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THE CHEAPEST IN THE END

From the point of view of durability and efficiency.

Part of an installation (one row of several) of "Premier" Filterpresses with wooden plates and frames, 40" square, in the North of England.

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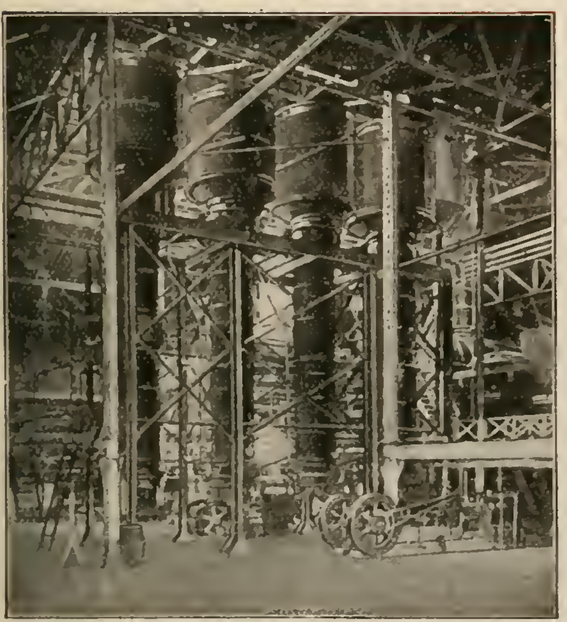

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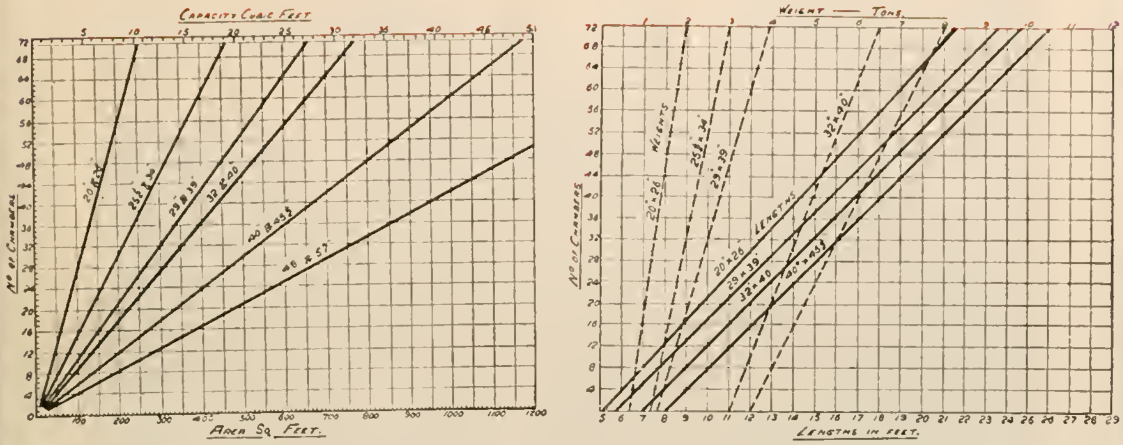

The above graphs give particulars of the capacity (per 1 in. of cake), area, weight and length, of our Wood Plate and Frame Filter Presses.

FOR GENERAL INFORMATION AND DATA ON THE WORKING OF FILTER PRESSES, SEE PAGE 63 OF THESE PROCEEDINGS.

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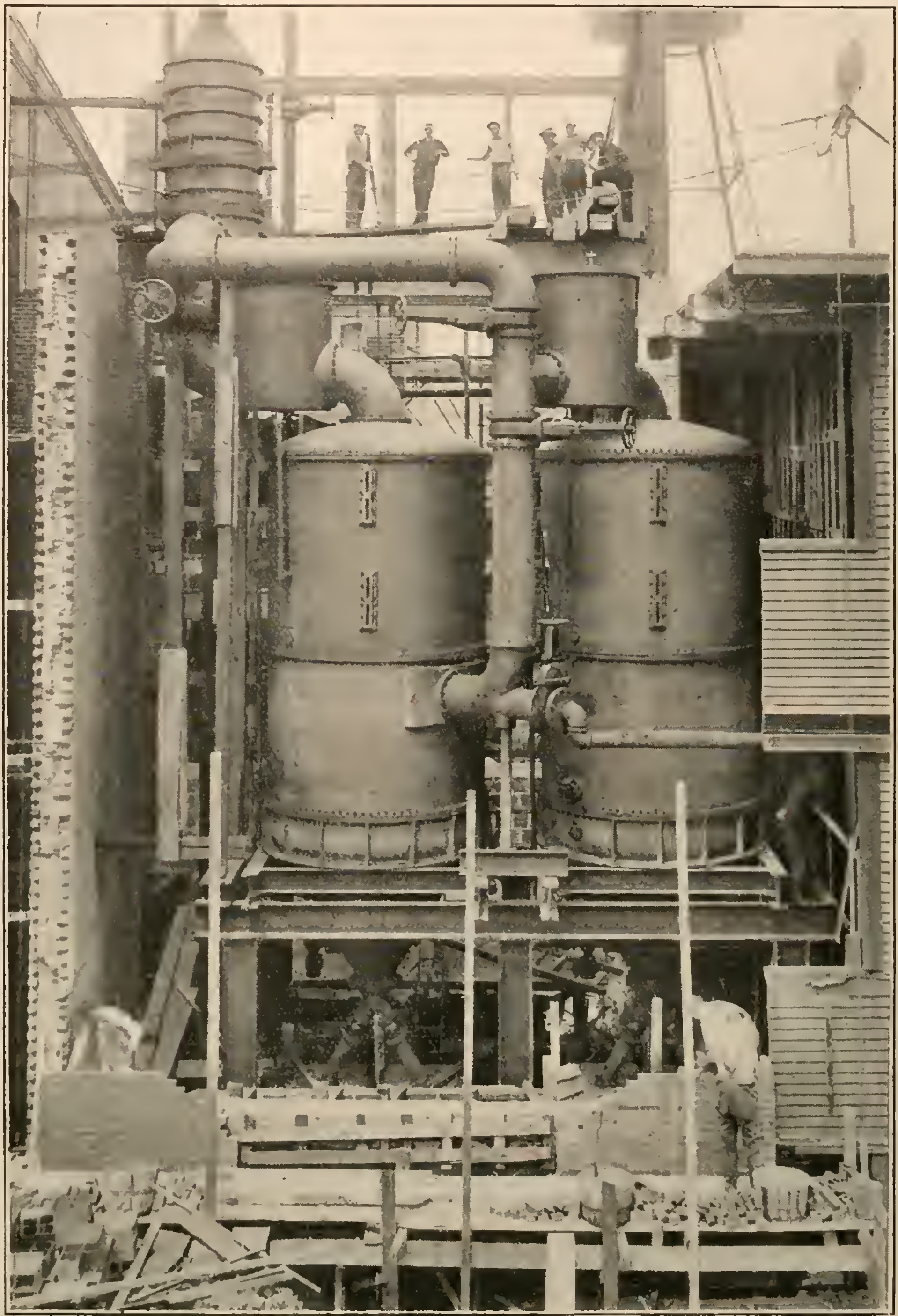

Photo of Double Effect Salting Type, with double salt boxes (partly obscured) recently erected by us in U.S.A.

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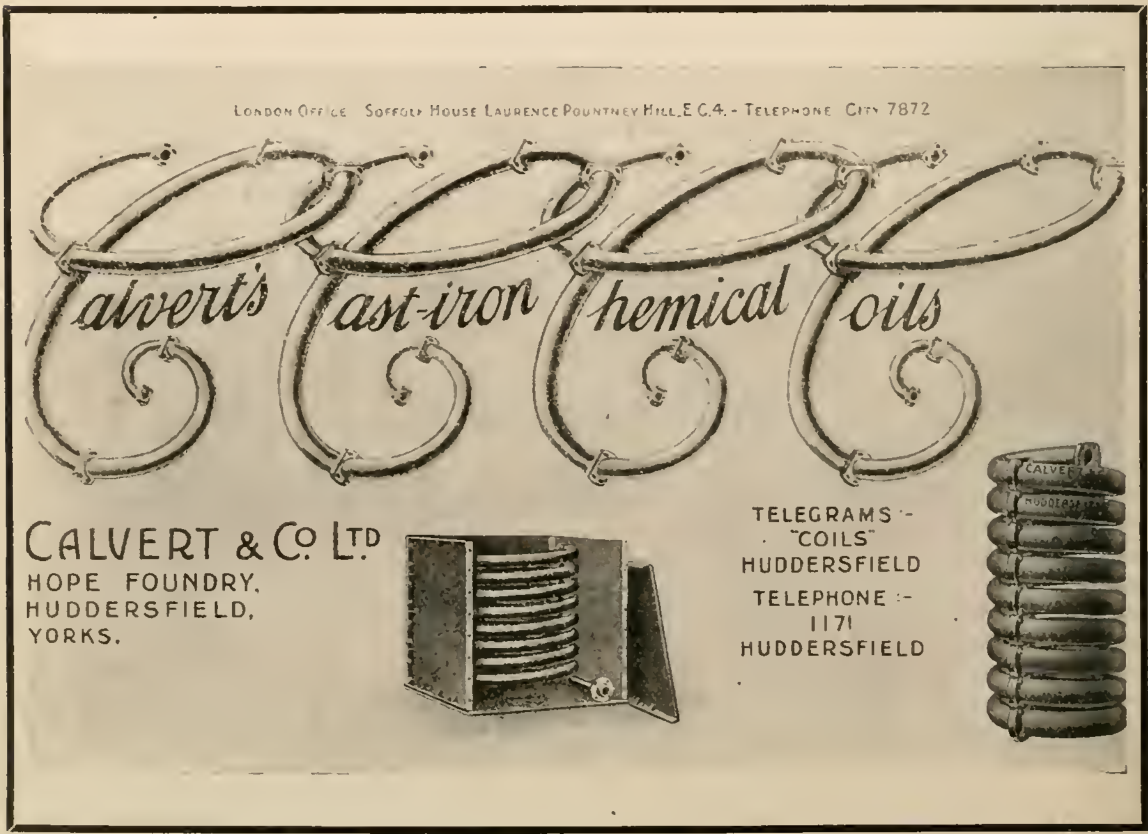

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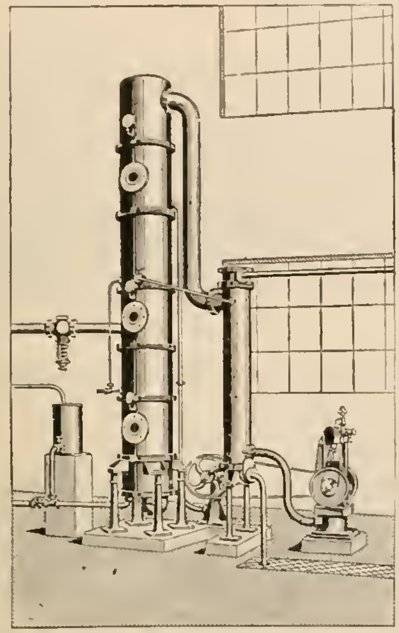

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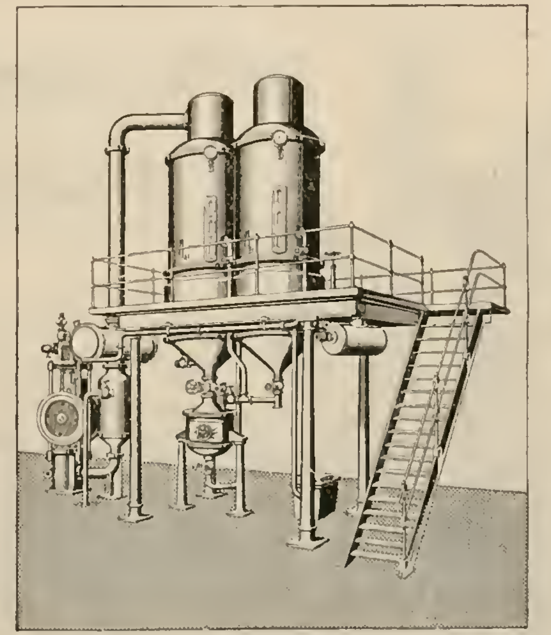

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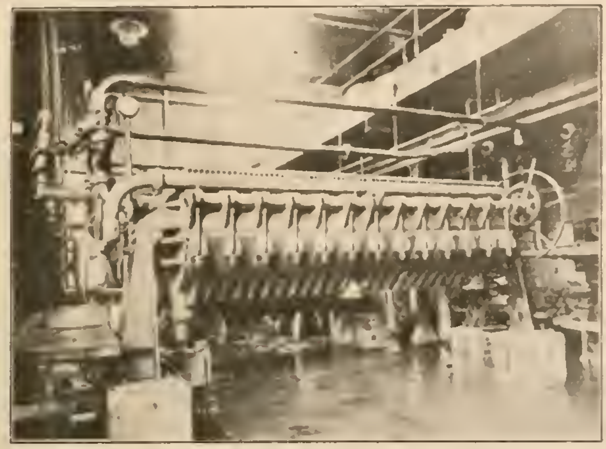

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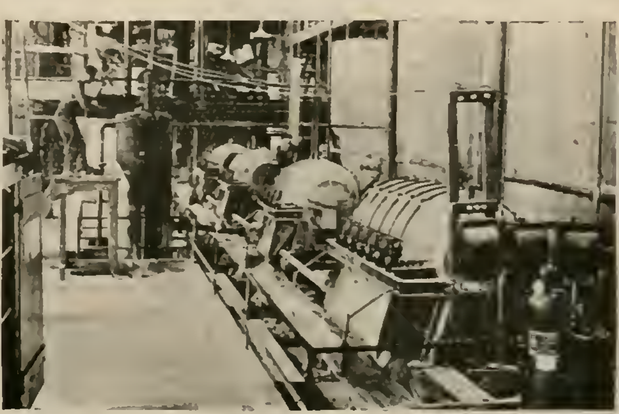

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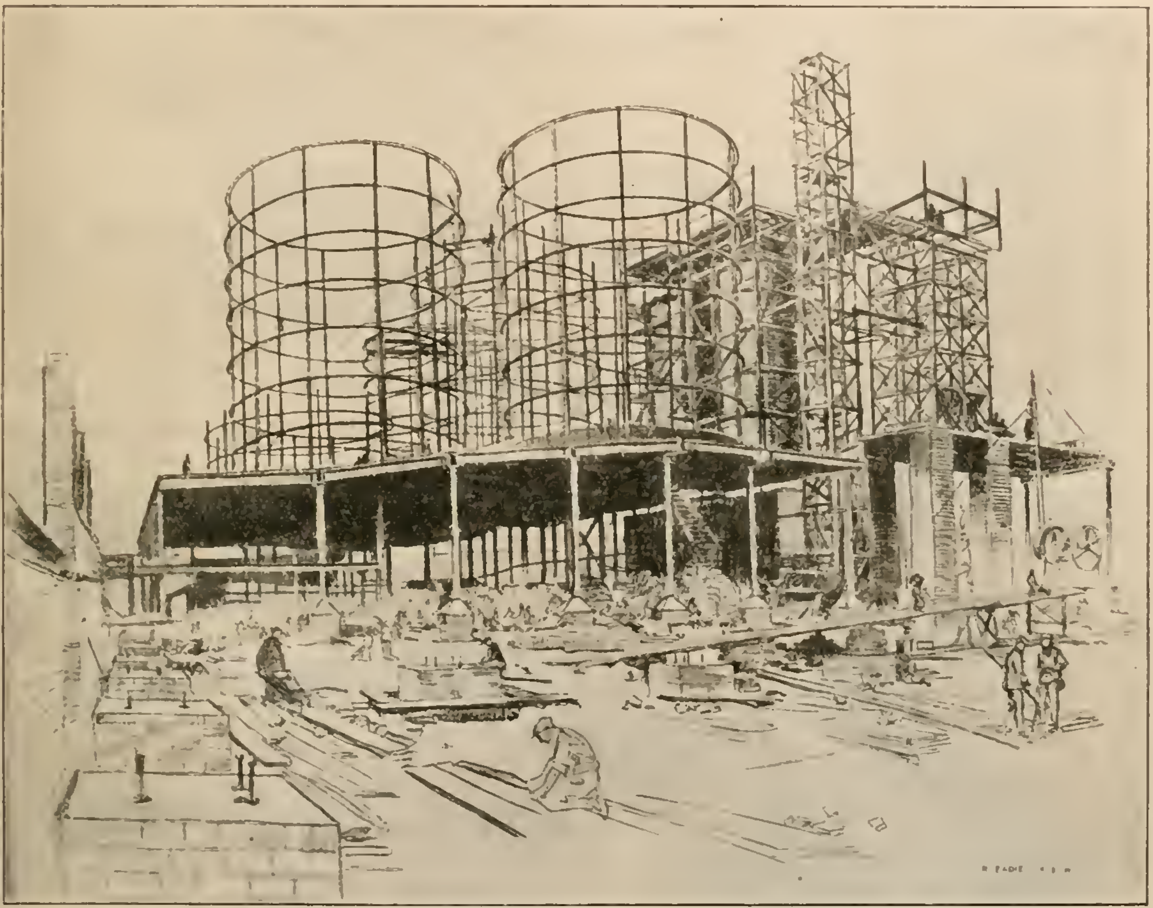

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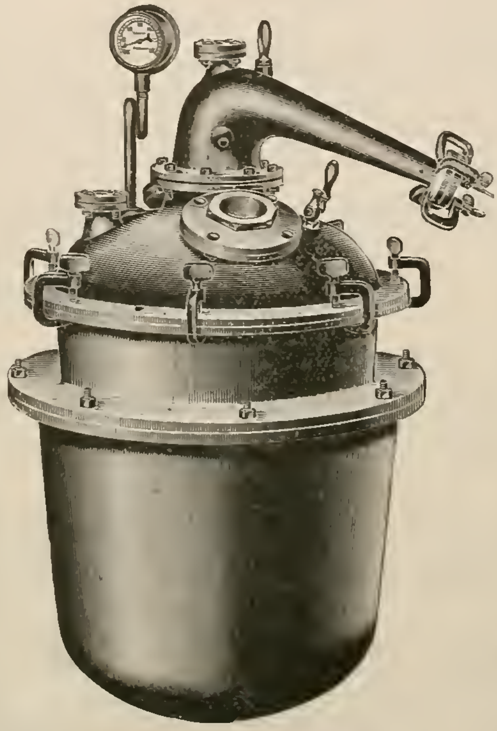

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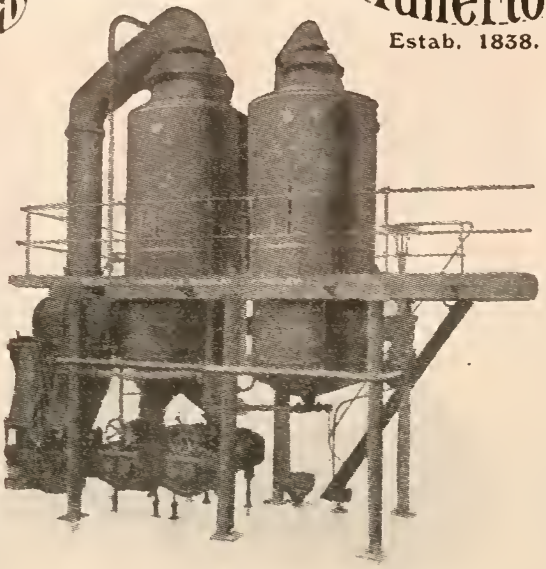

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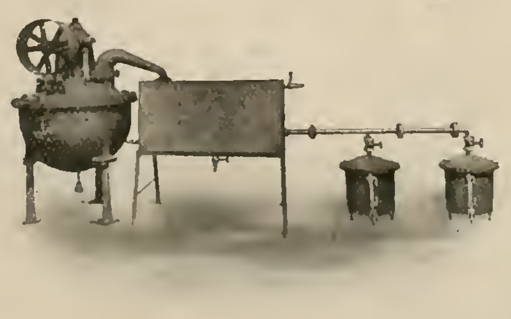

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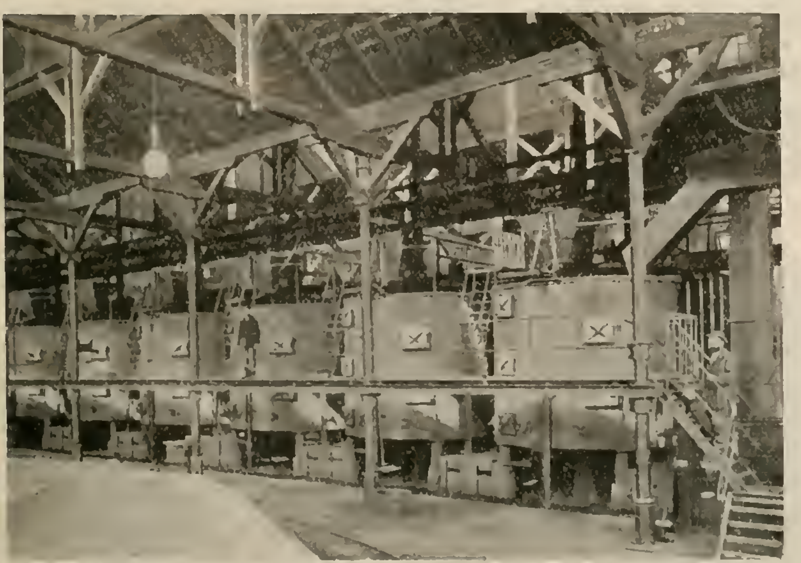

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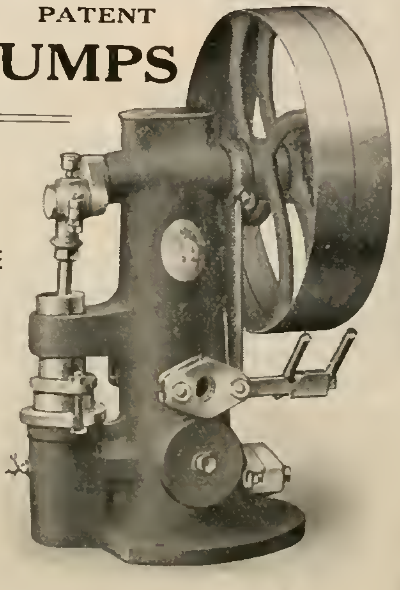

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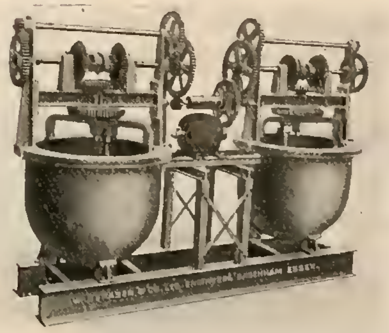

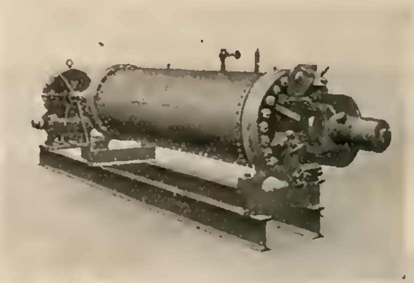

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J. ARTHUR REAVELL, M.I.M.E.

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THE SECOND

ANNUAL VOLUME OF PROCEEDINGS

OF THE

CHEMICAL ENGINEERING GROUP OF THE SOCIETY OF CHEMICAL INDUSTRY

1920

The progress of the Chemical Engineering Group during the period under review has been steadily maintained along the educational side, although the membership figures show a slight falling off from the number at the close of the previous year. Interest in the work of the Group has noticeably increased, particularly in general manufacturing and industrial quarters, and as a result much welcome support has been received from individuals and firms only indirectly connected with purely chemical productivity.

The activities of the Group Committee have taken in the main two directions—the issue of printed records of chemical engineering experience, in the form of tables and Data Sheets, and the holding of conferences on a more ambitious scale than previously. In both cases, the most unqualified success has been achieved. The Data Sheets published include very valuable figures and curves relating to:—

The properties of steam,
The properties of sulphuric acid,
The properties of carbonic acid,

as well as less intricate sheets dealing with such matters as tank capacity and the like. The preparation of many of these sheets has involved very extensive research into the literature of the subjects, as well as experimental work in the correction or verification of figures, the uncertainty of which seemed to demand attention. This branch of the Group's work has been directed by the convener of the Data Sheet Sub-Committee—Prof. J. W. Hinchley—and to him, and to research students of the Imperial College of Science and Technology, London, as well as to Mr. J. H. West, A.C.G.I., A.M.I.C.E., the best thanks of the Committee are due. It will be appreciated that the cost of such work as this undertaken by the Group must, in the nature of events, be greatly in excess of the small total received from annual subscriptions, and in fact the amount spent per member during the period under review was no less than 32s. 6d. per head, as compared with the subscription of £1 1s. The Committee is greatly indebted to a number of gentlemen and firms interested in the work of the group for generous subscriptions, without which its activities would of necessity have been accordingly restricted. In particular, their special thanks are due to Mr. C. S. Garland (one of their number) for defraying the cost of printing and issue of this number.

Turning now to the meetings side of the Group's endeavours, it is to be recorded that two Conferences have been held—one at Birmingham and one at Newcastle-on-Tyne, the former dealing with "Labour Saving Devices in Chemical Works" and the latter with "Filtration." Both Conferences were especially noteworthy in that a large number of actual users of the types of plant described in the several papers attended the meetings, and were able to give their very candid opinions as to the value of these devices in actual operation. In this connection the importance of actual attendance at the Conferences of engineers and works managers as distinct from the subsequent reading of reports of the meetings was very clearly brought out, for although the Publication Committee of the Group are at the greatest pains to report papers in extenso, there is a great deal of private discussion and conversation between actual manufacturers and users at the meetings, which, being too discursive for inclusion in a volume such as this, has considerable educational value to all present. An unusual feature of the Birmingham Meeting was the issue by the committee of a pamphlet in which a resumé of the papers was given, together with illustrations of the plant to be described. This was found to be of very great assistance in indicating the exact nature and scope of the papers, and only the excessive cost of such an issue has prevented the practice becoming standard. After the Conference a dinner was held at which over 120 people were present, including representatives of the City and its principal manufacturing interests, who honoured the Group with their presence.

The following day most of those who attended the meetings visited the Small Heath Works of the Birmingham Small Arms Co., and the thanks of the Committee are due to the Board and management of that company for the most interesting and enjoyable tour of the works they were permitted to make.

The Conference at Newcastle-on-Tyne on "Filtration" coincided with the Annual General Meeting of the Society. The importance of the subject of "Filtration" to chemists and chemical engineers was evidenced by the very large proportion of those attending the Annual Meeting who were present at the Conference, as compared with those who visited the meetings dealing particularly with the more theoretical side of chemical industry. Two papers, that of Mr. E. A. Alliott, treating of the principles of filter-press design and use, and that of Mr. Gee describing, with the aid of a cinematograph film, a new and highly novel departure in filtration practice, are particularly worthy of mention, as they bid fair to be regarded as standard works on the different phases of this important subject with which they deal. Here again, the presence of rival manufacturers of plant who were called upon to substantiate claims for the superiority of their appliances in certain respects over those of others, before a highly technical and critical audience, amongst which was a large proportion of actual users, proved to be of the very greatest value. The Group was greatly interested in seeing a centrifugal separator filtering machine in actual operation at the works of the International Paint Co., Felling-on-Tyne, and the Committee wishes to express here its appreciation of the courtesy of Centrifugal Separators, Ltd., and of the International Paint Co. in arranging for this visit and demonstration.

A matter of the greatest importance in the history of the Group is the very keen interest taken in its financial position by the Finance Committee of the parent society, and the very great value the Council puts upon the work of the Chemical Engineering Group was demonstrated by their insistence, although the Society's finances were then in a very straitened condition, on providing a very substantial sum to assist in carrying on the work of the Group. Negotiations are still in progress for a more satisfactory and permanent working arrangement, and it is hoped that this will be completed in the near future. The committee have to express their very deep indebtedness to Dr. Miall and Mr. Evans (Hon. Treasurer of the Society) for the public spirit they have evinced throughout the whole conduct of the conversations.

The Conference at Newcastle concluded the Group's work for the year, and there is now only to be recorded the best thanks of the Committee to all who helped to make its meetings so interesting and so successful.

LIST OF OFFICERS AND COMMITTEE, 1920.

The Committee and Officers of the Chemical Engineering Group, and the names of the Honorary Correspondents or Local Sectional Representatives for 1920, are given below:—

Chairman: J. Arthur Reavell, Esq., M.I.M.E.

Vice-Chairman: E. F. Armstrong, Esq., D.Sc., F.R.S.

Honorary Treasurer: F. H. Rogers, Esq., M.I.M.E.

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Birmingham.—H. T. Pinnock, Esq., F.I.C.
Bristol.—E. Walls, Esq.
Edinburgh.—J. W. Romanes, Esq., B.Sc.
Glasgow.—James MacGregor, Esq.
Liverpool.—A. Holt, Esq., M.A., D.Sc., F.I.C.
London.—A. E. Berry, Esq.
Manchester.—Howard Cheetham, Esq.
Nottingham.—H. Calam, Esq.

THIRD CONFERENCE.

LABOUR-SAVING DEVICES IN CHEMICAL WORKS.

BIRMINGHAM, APRIL 23, 1920.

The third conference was held on Friday, April 23, 1920, in the University Buildings, Edmund Street, Birmingham. The subject for discussion was "Labour-Saving Devices in Chemical Works." There was a representative attendance. Two sessions (afternoon and evening) were held, the chairmen being respectively Mr. W. A. S. Calder (managing director, Messrs. Chance and Hunt, Ltd.), in the unavoidable absence of Mr. E. G. Hunt, who, it was stated, had been called away in connection with labour matters, and Mr. C. A. Smith (Messrs. Edwin Danks (Oldbury), Ltd.). Following the afternoon sitting, the members of the conference dined together at the Grand Hotel.

The evening session was resumed at 7.30 o'clock.

The CHAIRMAN (Mr. Smith) said such conferences were valuable. They assisted in the creation of the right kind of atmosphere. It was necessary for chemical science to overcome the national indifference shown towards it. It was the function of the Chemical Engineering Group, and other such organisations, to concentrate with the object of arousing enthusiasm and creating an atmosphere in which chemistry might thrive and come into its own, just as did mechanical engineering in the Victorian age. When the industrial and scientific history of the early part of the twentieth century was written, it would be found that chemical science had been one of the greatest factors.

MR. TALBOT said he did not desire the conference to separate without giving a public expression of their thanks to the hon. local organiser of the conference—Mr. F. R. O'Shaughnessy, the hon. sec. of the Birmingham and Midland Section of the Society of Chemical Industry. Great success had attended his efforts. He himself had done a certain amount of work, but it was quite clear that unless he had been intelligently backed up in Birmingham the present success could not have been attained. Mr. O'Shaughnessy's help had been invaluable. (Applause.)

MR. O'SHAUGHNESSY, in reply, said any work he had been able to do as organiser had given him great pleasure, and he hoped it had contributed to the success of the conference.

A vote of thanks was passed to the chairman on the motion of Mr. C. S. Garland.

The CHAIRMAN, in reply, said he congratulated himself upon making the acquaintance, at a distance of so many distinguished gentlemen in the scientific world. He firmly believed that science held the key to the solution of nearly all the problems that confront us.

The conference then terminated.

On the following morning a number of members paid a most interesting visit to portions of the works of the Birmingham Small Arms Co., where they were accompanied by Mr. F. C. A. Lantsberry, F.I.C., and his assistants.

SOME NOTES ON PORTABLE CONVEYORS AND TRANSPORTING TRUCKS.

BY C. J. GOODWIN, A.C.G.I., B.SC., A.M.INST.C.E.

The handling appliances mentioned in this contribution are those calculated primarily to replace wheelbarrow methods, an extravagance of human effort, which when adequate quantities of materials are in question should be impossible under modern conditions. Although portable conveyors have been used for years, such machines have usually been crude and heavy, and it is only in recent years that their design, manufacture and, above all, standardisation have been studied seriously. While robust construction is necessary to meet the serious wear and tear occasioned in handling heavy materials, a conveyor that really merits the term portable must be light in weight and adaptable in a standardised form to the greatest possible variety of uses. Capital outlay and the equivalent cost of hand labour (not neglecting the possibility of subsequent increases in wages) are the chief factors in considering the adoption of portable conveyors and similar plant.

Assume, for example, that the local rate of pay is £3 per week or £156 per year, and that it is proposed to write off the cost of the machine in five years. Five years' wages represent £780, and we will assume that £600 only in capital need be raised by way of a loan. The following table shows the way in which the loan is repaid, the total paid out being £780:—

	Capital owing.	Annual Amount redeemed.	5% interest and 5% depreciation.	Total paid.
1st year	600	120	60	180
2nd year	480	120	48	168
3rd year	360	120	36	156
4th year	240	120	24	144
5th year	120	120	12	132
				£780

During these five years the average annual outlay, exclusive of running expenses, is the same as that formerly paid in wages, but at the end of the period the machine, somewhat depreciated, is still available for a further period of usefulness. It may, therefore, be said that under normal circumstances a capital expenditure of £700 to £1000 is economically justified on a handling installation which dispenses with the services of one man. The running expenses of the machine in such cases are not appreciably greater than the cost of running and supervising labour.

It is not the purpose of this paper to describe in detail the design and construction of the various types of portable conveyors, loaders and trucks which are on the market, and the slides, photographs and models will suffice. On the other hand, it is germane to give typical particulars as to performances, working expenses, maximum inclination —in fact, chemical engineering data.

Modern portable conveyors are made in lengths from 15 to 60 ft., mounted on wheeled trucks and built up in standard sections to give any desired length in multiples of 3 ft. The wheels of the trucks may be made to swivel in order that the conveyor may be traversed or made to describe a circle with the loading end as the centre; alternatively, the conveyor may be supported in the middle and suspended from a wood track or wire cable by an overhead trolley. For ordinary bulk materials the maximum practicable inclination is about 25 degrees, and by providing steel flights with a troughed conveyor, inclinations up to 35 degrees are possible at reduced capacity.

Under average conditions of loading the following outputs are attainable:—

Width of belt. ins.	Capacity, tons per hour. Coke.	Coal.	Earth.	Cement.	Fine Dry crystals.	H.P. of motor required according to length.
18	17	30	43	53	57	3 to 5
24	31	52	78	93	100	3 to 7½

The outputs of conveyors with steel flights for inclinations up to 35 degrees is about one-half of those given above, and in both cases the actual power consumption is considerably less than the rated output of the motor.

Comparison of cost as against hand labour.—We will assume that trucks of coal are to be unloaded and taken to a storage pile or hopper 30 or 40 ft. from the railway track; further, that 20 tons have to be unloaded daily.

Hand method.—This would be done by shovelling from the truck into wheelbarrows, wheeling up an inclined runway, dumping, and returning empty to the truck. Two men to unload the two trucks and feed into barrows in one day. At least three men would be necessary to wheel and dump the material.

Assuming daily wage of these five men averages 13s. each per day, this, for a working year of 280 days, would cost in labour £910.

Mechanical handling.—This operation would be performed by a portable conveyor, say, 50 ft. long, working on an incline of, say, 30 degrees. The receiving end remaining stationary at the truck door and the discharge end swinging round in an arc of a circle. The smallest type conveyor made would handle the quantity we consider in less than one hour, but it could not be hand fed from the truck at this rate.

Let us assume that two men are employed to shovel from the truck into the conveyor-receiving hopper. These two men would unload the two 10-ton trucks in one shift. The cost would work out as follows:—

	£
2 men at 13s. per shift each for a year of 280 days ..	364
One portable 50 feet conveyor with 3 h.p. electric motor and wheel truck. Capital cost £500. Interest at 10%	50
Sinking fund, assuming the conveyor has a life of 4 years ..	125
Cost of electric power at 5d. per kw. hr.	90
Cost of 1 belt renewal per year	64
Repairs, &c.	25
Total ..	£718
Yearly saving by utilising conveyor	£192

This yearly saving increases very greatly as the quantity of material to be handled increases, *i.e.*, as the conveyor is worked more nearly up to its capacity, but the above example has been purposely selected in order to demonstrate the saving which is possible even under unfavourable conditions.

If double the above tonnage had to be dealt with the saving effected would be about £800, or similarly if the conveyor could be kept employed on loading or unloading work about the factory when not engaged in its main work, a considerable further saving could be effected. Its portability makes this easy.

For places where no electric power is available, this machine can also be supplied with self-contained petrol engine.

It is obvious that similar calculations are equally applicable for other materials, and, of course, each case must be taken on its merits. In considering such an installation the saving of time is often very important, particularly if demurrage is payable on railway trucks, barges, or drivers of carts are kept idle awaiting their turn. Combinations of two or more portable conveyors are often preferable to a single conveyor, especially when the distance traversed exceeds 30 ft., and it is hardly necessary to illustrate the great variety of such combinations which are possible for unloading, reclaiming from the store pile, &c. Some portable conveyors are made with skirt plates at the sides of the conveyor, increasing the carrying capacity and to prevent the material from rolling back. In this way a 12-in. conveyor with skirt plates is equivalent to a troughed conveyor of about 20 ins. width.

Use of bucket unloaders.—It is obvious that hand labour is not entirely eliminated by a portable conveyor, and, for instance, when reclaiming from a storage pile the material must be shovelled towards or into the lower end. Experience shows, however, that it is much easier to do this than to shovel the material in the ordinary way, and there is also a remarkable tendency on the part of the workman to increase the quantity handled to keep pace with the insatiable appetite of the conveyor. Thus one man can feed about 30 tons per hour of material of 1 inch and under into the end of the conveyor provided the pile is more than 8 ft. high. The bucket loader is, therefore, useful as an auxiliary labour-saving machine, used where trucks, carts, or conveyor have to be loaded from a storage pile, and when used with the belt conveyor makes a very flexible material handling combination.

The bucket loader requires little description, the main feature being the feeding device, which in this case consists of a rotating double disc which digs out of the pile to a width of 5 ft. instead of bucket width. The rotation of the discs carries the material to the centre, where it is picked up by the buckets. As the discs rotate, their motion is transmitted through gearing to the rear wheels, propelling the loader forward into the pile; two speeds forward (50 and 140 ft. per minute *away* from the pile) and two reverse (25 and 70 ft. per minute *into* the pile) being provided.

With other types of wagon loaders a "flight" conveyor feeding attachment is used, consisting of an adjustable inclined scraper mechanism to deliver the material from the pile to the foot of the machine.

For purposes of comparison of costs we will assume that railway trucks have to be loaded from a pile of material or coal lying alongside the trucks. If of the self-feeding type, this material has only to be guided on to the revolving discs at the foot of the elevator. Its capacity is up to 1 cu. yd. per minute.

We will assume it is desired to load 30 tons of material per day into the trucks.

Hand methods.—The material is shovelled into wheelbarrows, which are wheeled up and tipped into the wagons. It would take at least three men to shovel 30 tons into the barrows daily, and another five men to wheel and dump into the trucks. On the same wage basis as before the labour costs for one year would amount to £1,456.

Mechanical handling.—If a self-feeding bucket loader were employed, two men could easily feed the material on to the discs at the foot of the conveyor, and one operator would be necessary to run the bucket loader. The yearly cost would work out as follows:—

	£
2 men at 13s. per day each for a year of 280 working days	386
1 operator at 17s. per day	238
1 self-feeding bucket loader with 7½ h.p. electric motor. Capital cost £840. Interest at 10%	84
Sinking fund, assuming machine has a life of 8 years ..	105
Cost of current, 5d. per kw. hr.	150
Repairs, &c.	25
	£988

So the saving effected even under conditions where the machine is working at a small fraction of its full capacity amounts to £468 per year.

Unfortunately space will not permit of the consideration of other types of unloaders for barges, special screening and dust eliminating devices, and of the presentation of diagrams, lay-outs and schedules for bulk storage and handling. Sufficient has been said to indicate that portable conveyors are definitely applicable for the handling of bulk materials in large quantities, and frequently, and perhaps unexpectedly, economical in smaller works and for quantities of 20 tons and less per day, particularly if the conveyor can be used for different materials in various parts of a works or for loading or stacking sacks, bags, &c.

Transporting trucks.—Where packages, boxes, carboys, jars, bottles, cans, drums, &c., are handled in large quantities, transporting trucks are eminently applicable. The goods are stacked on wooden platforms standing 8 ins. or 9ins. above the floor, and the portable truck, after being pushed under the platform, raises it above the ground and takes it to wherever it is required. Thus each platform becomes a truck and a considerable saving in capital outlay is the result. These trucks are also useful for assembling machinery which is to be subsequently moved elsewhere.

For larger outputs and for loading into carts, lorries or railway wagons, the use of a tier truck is indicated.

The present is a transition period in which any additional capital invested for the reduction of manual labour will pay a good dividend owing to the constantly increasing demands for higher wages of the unskilled workers of the country. Ultimately half of the men formerly employed in fetching and carrying may have to find new spheres of labour, and with increases in wages, mechanical appliances will continue to gain favour, except possibly in smaller works. In order to maintain our industries in competition with the rest of the world, our aim must be to avoid employing labour for work which can be carried out better or more efficiently by machinery, apart from the advantages and economies which inevitably result from that reliability, continuity and automatic operation which mechanical handling appliances alone can provide.

In reply to questions Capt. Goodwin pointed out that any particular type of plant must be taken on its merits. The life of the plant was what the purchaser chose to make it. The average life of a belt was usually about three years. Telphers or pneumatic conveyors were better suited for handling large bulk and also if continuous use were required. His object was to show what might be adequate to serve small works and manufactories where it was not possible or practicable to spend large sums on such plant. A saving could often be shown of putting in a portable conveyor where continuous working was not required. A conveyor of the kind described, about 30 ft. long, would cost from £200 to £350, and it would frequently be quite adequate for the unloading of barges, though if the work were on large scale lines air suction might be advisable. The cost of bucket unloaders was about £750. As to transporting trucks, there was a considerable saving in cost by having a platform instead of a truck standing idle for each operator. The truck would take a load of about 15 cwt.; a larger size of 3 tons capacity was made.

Capt. Goodwin added that his object of giving the paper was merely to draw attention to the fact that there were serviceable portable conveyors, although he had not seen many in use in this country. He had no doubt they would be used to a considerable extent in the future. He had no interest in any particular truck or conveyor.

A question was asked as to whether the movable trucks could be used safely for the handling of carboys containing liquids in chemical works.

Capt. Goodwin replied that a transporting truck of the kind described was eminently suitable for the conveyance of carboys. If there were any danger of spilling acid &c. the truck should as a protective measure be covered with lead or other suitable material.

Mr. Blyth was of opinion that this method of portable conveyors would be useful applied in conjunction with other means of handling. They might be of value. worked with a telpher plant, in bringing the material in the straight line of the machine. Coal could be easily raised from barges. There were many cases where it did not pay to instal a telpher line, and where it was better to place the coal on the bank. If the conveyors were efficient and did not require a great expenditure to keep in order, and were built robustly, he believed there would be a considerable field for their usefulness. As to the use of the bucket apparatus, and the suggestion that one man could feed per hour about 30 tons of material while by hand methods it would take three men to shovel 30 tons into the barrows daily, it seemed to him that the difference was too great. He felt also that the estimated yearly cost was inadequate, though it appeared that with a more liberal allowance for administration &c. that a considerable saving would accrue.

Capt. Goodwin said he had purposely quoted extreme cases. The difference referred to would, in any event, be most substantial, but he desired it to be understood that his estimate of one man feeding in the material was doing so on the avalanche principle. As to maintenance, he had taken a figure of 20% to cover interest and other items: an average of 10% for eight years.

Mr. J. W. Parkes asked what the experience was with automatic bucket rubber belt conveyors in the conveyance of broken pyrites, pebble phosphate and coal.

Capt. Goodwin replied that he saw no difficulty as to the using of a rubber belt for the conveyance of broken pyrites. The "life" would be about eighteen months. Coal was regularly conveyed.

Mr. G. King asked for information as to the maximum load a truck elevator would carry.

Capt. Goodwin replied that the question of the load was dependent upon the amount of the "overhang." The load became smaller as the "overhang" increased.

The conference then adjourned. Mr. Smith presided at the dinner, at which about 100 members were present. and the loyal toast was duly honoured.

THE IMPORTANCE OF MECHANICAL HANDLING OF MATERIAL IN ITS RELATION TO PRODUCTION COSTS.

BY H. VARNDELL.

In the time which we have at our disposal, I should like to give you a few details in endeavouring to show that mechanical means of handling material are, wherever judiciously applied. infinitely superior to the elementary methods of transporting by hand labour.

This phase of material handling is, as a rule, looked upon mainly from the point of view of reducing the amount of unskilled labour to a minimum in the workshop, warehouse or despatch rooms. There are many instances where, if mechanical conveying was adopted only to assist productive labour. the cost of its installation would soon be paid for by the assistance that it gives to skilled workmen, and its consequent effect upon the reduction of manufacturing and handling costs.

Mechanical precision and transportation, as in other phases in engineering, reduces allowance for error and damage to goods which must always be made when relying largely on the human element. One well-known firm, when recently discussing the possibilities of elevators and gravity carriers for handling china ware, declared that the contemplated installation would soon be paid for by preventing the heavy amounts lost by breakage and damage under the present methods of manual carrying.

There is little doubt that the extensive use of all types of transporters in the Army and Navy bases in England, France, and America during the war has opened the eyes of many employers of labour to the unqualified advantages derived from these methods.

During the early part of the war it was estimated that the British used 200,000 men for a long time in France handling the freight between the ship side and the various bases near the front. The rail roads did not have adequate facilities, piers and wharves did not have labour-saving devices, and man power therefore had to be depended upon for nearly everything. With constant influx of all kinds of material into France, the lack of handling facilities very soon created a chronic state of congestion.

Under these conditions it was necessary to establish relays of men. One gang of 30 men would take boxes on their shoulders. carrying them 300 ft., set them down and walk back to get another load. Meantime, another gang would pick up the boxes, carry them 300ft., set them down and walk back. This process was repeated throughout the entire distance the goods were to be conveyed.

At a later date, patent gravity carriers were used for this work, with the result that about 70 per cent. of these men were released for fighting and other purposes, and the freight was handled in much less time and at far lower cost. As an indication of the impression given by this type of carrier, it may be mentioned that within a short time after the first tests over 40 miles of carrier was supplied to the quartermaster's departments of the Allies.

The general principles of the conveying of material in and about factories and warehouses etc. are based solely on the applying of the machines to minimise the amount of rough labour and to assist skilled labour. The expert in freight handling first considers whether the operation of transferring material can be done through the force of gravity, as this is obviously the method necessitating the lowest operating costs and in most cases less initial expense.

It is becoming an acknowledged fact that in a great many cases the gravity system is easily superseding other conveyor systems, the advantage being that it is always ready for use, requires no power to operate, and can be easily moved about if required, and can be used as a storage space.

In long runs the necessary gradient is obtained by inserting inclined elevators which receive and raise the goods to the necessary height to obtain a further length of travel.

The force of gravity can only be applied, of course, when the material is required to be taken from a given point to somewhere in a lower horizontal plane. When this condition exists and other factors permit, the well-known types of conveyors, such as patent gravity carriers, spiral chutes, and lowerators are most generally used.

In construction and operation the patent gravity carrier is the essence of simplicity. It is generally made in standard lengths of 8 ft., with coupling hooks for joining up length to length to cover the required distance. In construction it consists merely of two parallel side frames, with rollers fitted across on spindles at regular intervals. The rollers are steel tubes of 14 gauge and 2¼" diameter, and are fitted with ball bearings at each end made out of steel stampings. Boxes, crates, cartons, etc. are merely placed on the carrier and allowed to move forward by gravity, the carrier being set at a sufficient gradient according to the speed at which the goods are to travel. For general purposes this gradient varies from 3 to 5 per cent.

All that is necessary when the conveyor is required for use is to connect up the 8 ft. lengths until the conveyor is suitably long, resting on any old boxes available, or, in the case of a permanent installation, on graduated supports. After use it is the work of only a few minutes to disconnect the lengths and take them away to their place of storage, or to another point where they may be required for use.

To raise goods from one floor to another, or through a series of floors, power-driven machines, on the continuous chain principle, are mostly employed. On the latest types of continuous elevators it is the practice to automatically pick up the crates or packages etc. and automatically discharge them at a given floor above. Where it is necessary to distribute material on various floors, suitable types of conveyors on each floor may be coupled up to take discharge from the elevators when the operation becomes almost entirely automatic.

In many of the most modern firms, the machines performing the various processes in producing a finished article from raw material are actually fed by suitable types of carriers, thus eliminating the carrying by hand of material from one machine to another.

In some cases a single line of gravity carrier is all that is required, but in others it becomes necessary to synchronize the speed of the carrier with the speed of the slowest machine in the manufacturing operations. As an instance of this, the bottling stores of a brewery afford ample illustration. After washing, the bottles are taken by a belt conveyor to the filling machines, and from there on to the stoppering machines, and so on until finishing at the labelling machines, where they are taken by gravity carriers to the despatch room. In such a scheme the conveyor must necessarily work at a speed consistent with that of the slowest process. Where human labour does this work, the slowest factor is almost invariably the human element itself, and it is this that is responsible in many plants for a total production less than that of which the machines would be capable were they properly kept supplied.

It is obvious that any factory which bases its works organisation on mechanical methods of manufacture and handling, thereby eliminating all necessary waste labour, naturally obtains a continuity of process throughout the works which spells consistency with its consequent high production at low cost.

It would be very interesting were we able to arrive at statistics showing the amount of time alone spent by manual labour in carrying the myriads of articles in present use. As far as this applies to factories, warehouses, and despatch rooms, almost as much time as is spent in carrying goods is taken by the men in returning empty-handed to their respective spots to take up something else to deposit somewhere else.

It cannot be said that any employer of labour would willingly pay heavy sums of wages to labourers, unless from philanthropic considerations, if he knew he could obviate such expense by the adoption of mechanical means.

The area of many premises is dependent not entirely upon the output of the concern, as one would think, but partly on the amount of room required by the employment of labour for handling material. This little point is worth the consideration of many who do not feel quite justified in paying such heavy annual rents. Conveyor plant requires far less room, and on innumerable occasions a labour-saving installation has effected a very material clearance of ground space which previously was littered by trucks, tracks, idling labourers, and the paraphernalia of the conservative methods of progress.

In conclusion, I would point out that it is very rarely the case that two transportation problems are exactly alike, and each one therefore requires to be treated on its individual merits. It is worse than useless to apply a low capacity machine in a situation requiring, say, three times the capacity than that of which the machine is capable. Also, it is necessary to point out the dangers that lie in installing machines of faulty workmanship, when a breakdown will hold up the operation of a plant and no spare labour is available to fill the temporary breach.

DISCUSSION.

MR. S. H. BLICHFELDT stated that the firm with which he was associated (the Maypole Dairy Co.) had a large gravity carrier installation. It did its work admirably. Boxes of 56 lb. weight were chiefly carried, but it seemed to him that the carriers were suitable for many purposes. They were easy to erect, and the maintenance cost was not great; that on the elevators was the greater.

PNEUMATIC CONVEYING OF COAL AND SIMILAR SUBSTANCES.

BY H. J. H. KING, M.I.MECH.E.

I have pleasure to-day in placing before this meeting details of a pneumatic suction plant, in connection with the power house at Messrs. Boots Pure Drug Co., Ltd., Island Street, Nottingham.

This power house is surrounded by the large chemical factories of the same firm, and it was very essential that all dust should be eliminated in the unloading of the coal for use. With this particular point in view the pneumatic suction plant was adopted in preference to bucket elevators and conveyors.

The problem was to move 20 tons an hour of coal of a quality from fine slack to lumps up to fully 4″ cube to a central bunker. The supply of coal was principally brought by barges, but provision was made on the opposite side of the power house for a supply of coal from other collieries by means of road transport, in the event of a severe winter when the canal may be frozen up, or dock gates required repairing.

The intake hopper or storage bunker is situated at a height between 70 to 80 feet from the water level, and it consists of a wrought iron bunker with numerous outlets to the boilers below, but with sufficient capacity to contain 400 tons of coal. To perform this duty the suction plant consists of:—

First, a pump 28″ diam. × 14″ stroke, driven through gear wheels by a two speed Lancashire motor of 70 h.p. The pump is what may be termed a "dry air pump," having Corliss inlet valves and leather expansion valves. This pump has been tested by taking the air i.h.p. against the electrical h.p., and gave an efficiency of 78 per cent., and I may mention it is provided with ring-oiling bearings and lubrication arrangement for continuous working.

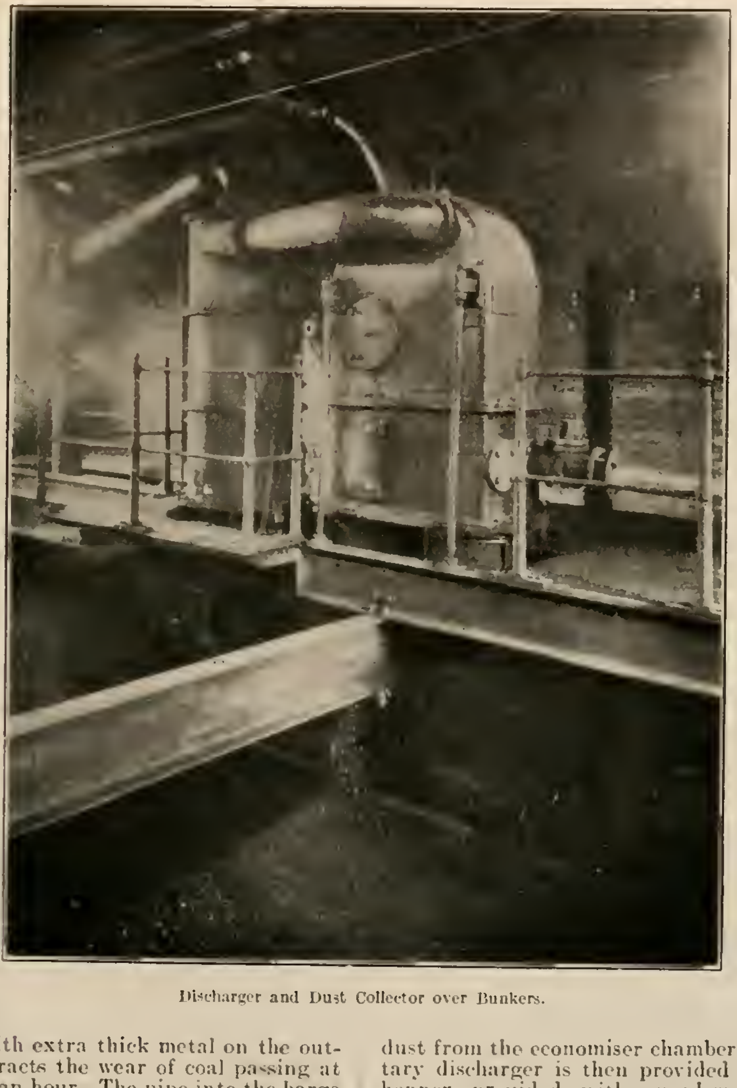
Anyone who is acquainted with the unpleasant conditions of coaling a ship at sea will fully understand the chief trouble to contend with in any coal suction plants must be to eliminate the dust, and in order to overcome this difficulty on this plant special provisions are provided. Close to the pump is provided an elaborate dust collector consisting of 16 flannel bags providing a large area for filtering the dust from the air before reaching the pump. The bags are placed vertically, and the incoming air is given a vertical downward direction. The bags are open on the inside to the incoming air, and the collector is provided with a large chamber at the top and a large chamber at the bottom, the bags themselves being open at each end. The air passes out radially from the bags before reaching the pump. The direction of the incoming air vertically descending allows a large quantity of the particles of very fine dust to be precipitated straight into the bottom chamber, as the velocity of the air is approximately 40 feet per second. On the bottom of the dust collector is provided an automatic discharge valve, which automatically discharges into bags any dust that drops through the bags. There is also provided a circular scraper, which sweeps down the conical section and automatically cleans the dust collector. This very fine dust is collected in bags and sold to the foundry trade for dressing moulds, and has proved to be a useful bye-product to any coal suction plant.

The pump and the dust collector are placed on the ground level in a separate engine house, and from the dust collector to the actual discharger over the bunker is approximately 100 feet of 10″ steel piping and special swelled bends of 10″ to 13″ diameter. The swell bends are to allow for an easy travelling round of each bend to prevent frictional losses. The coal discharger itself consists of a cast-iron vessel with two King's patent rotating valves in the form of a slightly conical taper divided into four sections, one portion of the circular valve being under vacuum, and the other under ordinary atmospheric pressure. The outlet of the valve is larger than the inlet to allow for the coal which is in the valve to drop out easily. Over each valve is also provided a four-armed sweeper to prevent any fine damp coal forming a cone inside. This discharger is provided with two inlets with fullway bored valves, so that the coal can be either drawn from the water side or from the land side at will. After the coal has been deposited in the main discharger, there is provided a supplementary discharger, consisting of a vessel 6′ 0″ high by 30″ diam., with two inlet pipes of 8″ diam. to provide a contra flow, so that any particles of the coal dust in the air will meet one another in the 30″ box, and in practice hit one another at an equal velocity, so that the small particles will be deposited by a supplementary discharge valve which is set to run very much slower than the main discharger valves. The main discharger valves are driven by worm gear, one right-hand thread, one left-hand thread, so the end thrust on the two worms is neutralised.

Suction Pipe—Land Side.

In addition to these ball bearing end thrusts, there is provided a small motor that drives all three valves, and is coupled up with an electrical device designed by Mr. Phillips, electrical engineer to Messrs. Boots Pure Drug Co. This arrangement allows that should anything happen to the top discharge valves, so that the small 3 h.p. motor cuts out owing to overload, then the main switch down below operating the main power motor also cuts out; this prevents any flooding of the pipes and dischargers. I may mention that the valves are so designed that a portion of the weight of each valve is carried by the vacuum, so that the vertical wearing lift on the valves when at work is very slight. The size of the intake pipes for the coal is 5" diam., and they are provided on the bends with heavy cast iron, with extra thick metal on the outside, which counteracts the wear of coal passing at the rate of 20 tons an hour. The pipe into the barge is provided with a flexible connection, and both flexible steel pipe and india-rubber piping have been used to couple up the nozzle to the vertical line pipe. This nozzle is made as light as possible for easy handling, and has an air intake pipe for the regulation of the quantity of air necessary to blend with the coal.

In regard to the theory of how 3 lb. of vacuum can lift 1 lb. weight of coal 80 feet at the rate of 40 feet per second, tbe explanation is that inside the pipe what takes place is a continual whirlwind, and in the range of the piping a gradual increase in size is provided in order to allow for the expansion of the air under vacuum, as between the coal barge and the pump, a continual increase in the diameter of the pipes necessary to allow for the expansion of the air. Slides will be shown illustrating a drawing of the plant, the water side of the installation, the land side, and the discharger over the coal bunker. The two last named illustrations are reproduced in this reprint.



Discharger and Dust Collector over Bunkers.

In addition to the duty of lifting coal from barge and from the land side, when no coal is required the plant can be used for the withdrawing of ashes from the ashpit, also for the fine flue dust from the back of the Babcock and Wilcox boilers; also flue dust from the economiser chambers. A supplementary discharger is then provided outside with ash hopper provided with supplementary discharge valve; also with a water feed to quench any live ashes that may be taken over. Drawings of the arrangements for dealing with the ash and indicator card taken from the air pump will be shown.

Although the average working vacuum is 10" of mercury, the pump can maintain a vacuum of 18" with extra power being allowed in the event of any extra duty being required for coal that may be damp, either due to leaks in the barges or bad weather in transit from the colliery to the power house. In practice we usually allow two h.p. per ton per hour, but it is possible on certain classes of coal to get 1¾ h.p. per ton per hour; this varies slightly owing to the human element being required to keep up constant feeding of coal to the nozzle by trimming, and in a long, narrow barge there must be a certain amount of movement allowed for to get the nozzle to the different parts of the boat. This plant has been running now for fully 18 months, and I am under the impression that in addition to coal there is a large field open for this class of machinery, primarily due to the very high wages now demanded in the labour world, secondly for the convenience, and thirdly for the absence of dust secured by using pneumatic suction plants.

Discussion.

Capt. C. J. Goodwin observed that reference was made by the author to the use of rather heavy cast-iron bends to compensate for the wear caused by the coal in passing round the bends. He inquired as to the rate at which the metal was worn away at those bends. He understood the rate of wearing was rapid, and he desired to know if a material harder than cast iron could not be used with advantage. Acid-resisting or silicon iron was successfully used in America in the construction of similar plants; it was very hard, and to machine it an emery wheel had to be used. As to coal, was there much difference in the efficiency of the plant and its working if the coal were damp or contained much moisture?

Mr. King replied that if the coal was small and damp, extra vacuum was allowed. As to the amount of wear at the bends, the bigger the radius was at the bends the less was the h.p. required. He could not state what was the amount of wear per lb., or how long the bends lasted.

Mr. T. Thornley asked for information as to the cost of such an installation, and of any serious technical difficulties in the working of the plant. He had not heard of a plant which was capable of carrying coal up to the dimensions stated.

Mr. F. C. Vokes inquired as to what was the normal experience in handling screened coal and ashes.

Mr. Tungay observed that he was keenly interested in the question of efficiencies. Had material of a higher specific gravity than coal been handled? And what was the experience with regard to the breakage of coal through the elevators and at the bends? He took it that the transit was fairly rapid.

Mr. J. Arthur Reavell inquired if the author had had any experience in raising material other than coke—such, for example, as damp crushed wood, sawdust, and material from the pits at tanneries.

Mr. H. Sissons asked if the apparatus were of use in dealing with fine slack containing up to 25% of moisture.

Mr. J. C. Mann asked if, and how, the method could be applied for the distribution of fuel in various parts of a chemical works yard. Could it be applied under pressure as in a vacuum?

Mr. A. E. Malpas stated that in a pneumatic installation at Liverpool with which he was familiar the wear at the bends was considerable, but as they were accustomed to large depreciation and constant renewals in chemical works too much importance need not be attached to that matter. Some years ago he considered the question of distributing soda ash between two points direct from the furnace to a crystal soda plant. For want of sufficient backing he did not, however, proceed with the scheme, although the position to-day would perhaps be reversed. They simply fell back on the ordinary methods by loading into wagons and shunting down to the job. The pneumatic method of the transmission of papers had long been adopted in the Post Office, and some years ago he had experience with an installation of this kind at a large works. It worked satisfactorily, though when there was excessive rain condensation took place in the pipes and the papers got very wet; but this difficulty was overcome by preheating the air used. He regretted the author had dealt merely with one suction plant dealing with coal.

Mr. E. G. Phillips, who was responsible for the working of plant described, stated that the experience with it was better than anticipated. The work of unloading the coal was done without raising any dust. If one tried one could not raise dust. The author had mentioned that the h.p. of the motor was 70; but that was the rating. The h.p. for a lift of 87 ft. and 40 ft. horizontally was not more than 40—45. It should be understood that the coal floated in the pipe in a stream of air. The amount of coal broken was small, and the result was similar with other materials. If coal were put through a right-angle bend it could be smashed to powder, but with an easy bend there was little breakage. The wear was at the bends, the "life" of which he estimated at six months. Only a portion of the bend was worn—the point at which the material impinged on the metal. A question had been asked regarding the conveyance of coal in an horizontal direction. Some time ago he had collected a large quantity of coke, and it was necessary to remove it from the side. A long series of pipes, including ordinary pipes for the conveyance of water, was laid (rags or red lead being used for coupling) for 305 ft., and with pipes in a vertical position for 87 ft.; and without difficulty the whole of the fuel was discharged.

Mr. King, in reply, stated that coal could be distributed without difficulty to various points. Portable discharges could be used as on a Telpher. Pneumatic suction was really supplementing Telpherage. Ordinary sea sand in varying stages of dampness had been conveyed: anything containing from 1% to 5% of moisture could be drawn; when it reached 8% or 10% difficulty arose because the material was apt to stick in the pipes. Many materials besides coal could be dealt with. There was no difficulty with fine materials. Chippings from tanneries could be conveyed; even steel nuts had been lifted. It was difficult to state cost, owing to the rising prices of materials.

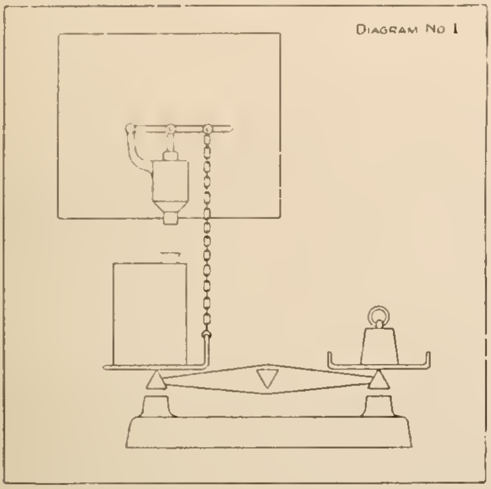
AUTOMATIC FILLING MACHINES FOR LIQUIDS.

BY H. F. BROADHURST.

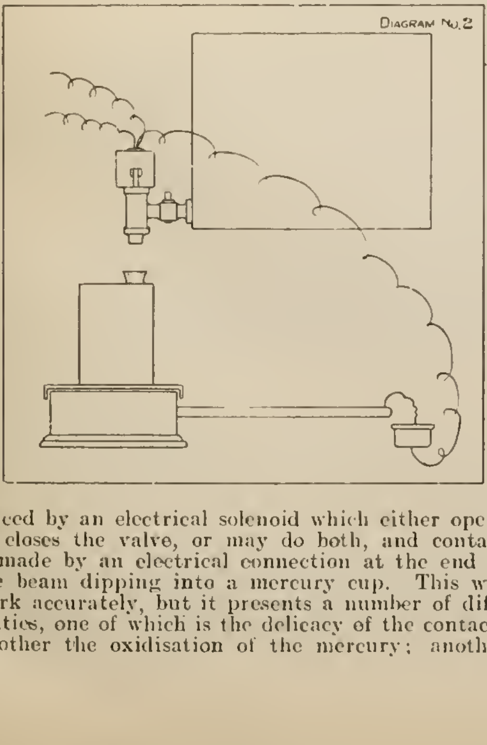
Filling thick liquids into tins has always been difficult and slow because they will not run clean out of a measure. Filling, for instance, heavy oils or varnishes, into narrow-necked tins means drawing off into a measure, pouring from the measure into a funnel, and waiting for the measure and funnel to drain, and then the amount poured into the tin is only approximately correct and there is a lot of drip and waste. For filling open-necked tins, such as the standard levertop, by weight, the usual method was with a jug and a pair of scales. This resulted in over-filling—as much as 5% of the material being given away—and considerable waste, and the average speed about four tins per minute.

These methods were only possible when paying a very low rate of wages; now the filling machine is a necessity. Such a machine will fill at more than six times the rate of hand-filling with absolute accuracy, and so cleanly that in addition to other advantages the whole cost of cleaning the tins is saved.

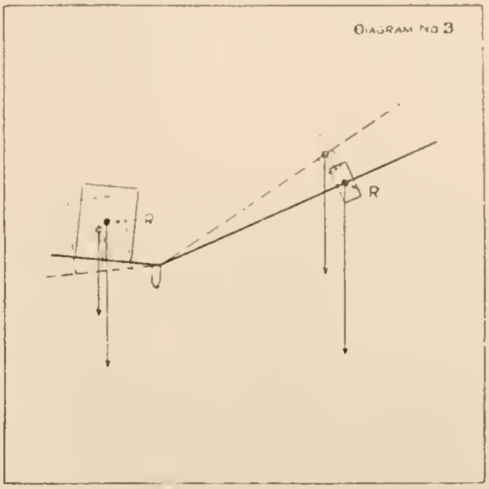
There have been a number of attempts at machines, and many manufacturers have made trials with machines of their own. Practically they all work on the principle as shown in Diagram 1, that is a filling valve, a pair of scales, and a connection from the scale-beam to some form of trip motion above the valve to allow it to close when the scale moves. The difficulty of this system is that when the scale begins to move it is balanced and has no power to operate the lightest trip motion until sufficient extra weight is put in to overcome the friction of the trip. If this were a constant error it would be all right, but it is not by any means. The friction varies, and this system will not fill 1 lb. tins within several ounces of the correct weight.

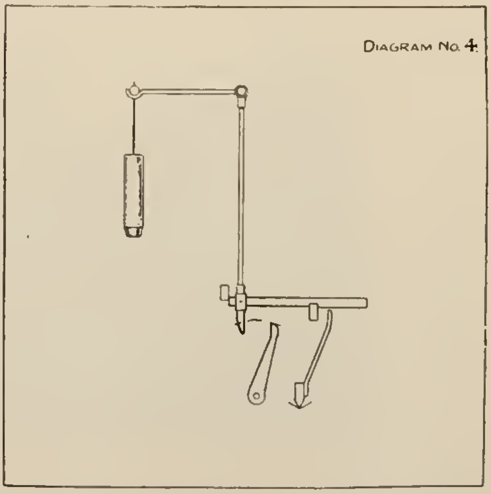


The next development is a similar sort of arrangement (see Diagram 2), but the trip motion is replaced by an electrical solenoid which either opens or closes the valve, or may do both, and contact is made by an electrical connection at the end of the beam dipping into a mercury cup. This will work accurately, but it presents a number of difficulties, one of which is the delicacy of the contact; another the oxidisation of the mercury; another the complication of having to put delicate electrical gear into a factory for the use of unskilled operators who never understand the machine.



The latest development which overcomes all the above difficulties is the bent-up weighing lever (see Diagram 3). In this case the weighing lever is not horizontal, and as soon as it moves the weights move inwards so that their leverage decreases as the scale falls, and the centre of gravity of the tin being well above the knife edges, it falls outwards and increases the leverage. This scale, as soon as it moves off its support, falls with an increasing speed and force, the load becomes heavier and the weights lighter, and after a very short and quick travel ample power is available to operate any sort of trip gear. This motion, which is patented in most countries for this purpose, is the basis of a satisfactory mechanical cut-off.





The cut-off used with this scale (Diagram 4) is a valve-lifting lever and a horizontal pawl which has a notch to keep it in the valve-open position. A trip arm attached to the scale-centres works under this pawl which for three-quarters of the scale travel does not touch, but during the last quarter when the scale is moving with considerable force, this arm comes under the pawl and raises it, allowing the valve to close by its own weight and giving a very sharp cut-off. An illustration of one form of the machine is shown by Diagram 5.

This shows a standard form of the machine as used for filling levertop or other tins with a large opening. In this, T, is the table on which the tin is placed and pushed up against guide (G). This table and weighing lever (WL) move on the steel bar cut into knife-edges (KE). This is a very simple form of weighing motion, but it can only be used with tins with large openings because the radial motion of the scale causes a movement of the top of the tin. This movement is only about ½ in., but it is too much for filling tins with small openings.

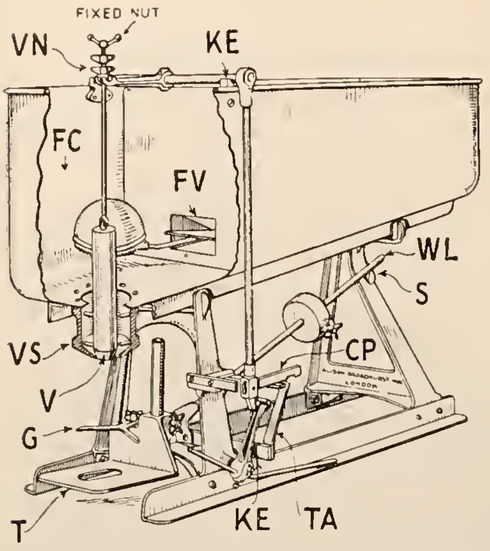


Diagram No. 5.

For filling the latter the scale has to be arranged with another pair of knife edges and a top centre. These knife edges form a parallel motion and give a straight up and down movement to the table. This type of machine has a store-tank holding about 10 gallons. The material to be filled in it and the front of this is divided off into a float chamber (FC), the connection between the two being made by the float valve (FV). This shuts off with about 3 in. depth of liquid in float chamber, and opens as required to keep this level constant. This gives a constant level for the filling valve as long as there is a supply in the store-tank. It is necessary to hold this constant head, and if the machine has been left standing full, material has leaked through the filling valve and filled the float chamber, it is necessary to draw some material off through the valve and put it back in the store chamber before starting to work, otherwise the first tins weighed out would be too heavy. These machines are hand-started; pressing the handle at the side pulls the catch-pawl (CP) forward, and in doing so raises the valve, the levers and shaft for this purpose being balanced on the top knife-edges (KE). When the scale moves, the trip arm (TA) comes under the catch-pawl, which raises it and allows it to slip off the notch, and the heavy valve (V) closes by gravity.

This valve is tapered at the end, and hollowed out inside, to leave a sharp cutting edge all round, and this edge meets another sharp edge on the valve seat (VS). This gives a non-drip valve, as no wetted surfaces are exposed when the valve is shut, and also the sharp edge of the valve and the angle of seating are arranged so that it cuts through any soft substance and closes tight, even in the case of paint skins or fruit skins getting into the valve.

The top fixed nut is arranged to revolve the valve on its seating to cut through any obstruction making it leak. The valve is guided on sharp points, shown projecting in the valve seat (VS). This gives an absolutely non-stick guide and the valve falls freely even when filling varnish, syrup, and such like sticky substances.

In a larger form of the machine there is only a float-tank, and this can be direct coupled to the main storage tanks by a flexible pipe. They are made up to the size which takes a 10 gallon drum, and the principle of the bent-up weighing lever to give a quick and certain trip to the scale to release the catch-pawl is the same on all of them; also in any of the machines the filling stream can be varied from full flow, which is 1½ in., to a stream of one-eighth of an inch in diameter, simply by regulating the valve nuts (VN) on the top of the valve rod, so that no changeable valves or valve seatings are required. Every part of this machine lifts off for cleaning and no tools are required to operate or adjust it, and a great point about the small shallow tank is that it is easily lifted off the machine and washed out.

The same machine fitted with a smaller valve and the parallel motion to the table as mentioned above is used to fill tins having very small openings, such as the cycle flask and metal polish tins, and these are filled very rapidly and with the greatest accuracy. With regard to filling bottles to any quantity, several hundred at each operation if required, this is possibly of more importance than tin filling, and new patents are pending to cover this development, but for filling bottles singly up to an average rate of about 20 per minute, the existing pattern of automatic filler is fitted with a small key, exactly like a telegraph key, to be operated by the fingers of the right band, and this key both opens and closes the valve. A support is arranged for the hand to rest on; the travel is very short, and it is balanced so that the pressure to operate is very slight.

This makes an exceedingly sensitive arrangement with which it is quite easy to fill bottles to an exact height, which cannot be done by either a weighing or measuring machine owing to the variation in weight and capacity of the bottles.

Operating the gear by the first fingers of the right hand is the only way to obtain quick enough motion to shut off accurately, particularly for small bottles; and foot operation of a bottle filler is like asking an operator to work a telegraph key with his foot. In some cases machines have been fitted with both automatic and hand-gear in order to fill either tins or bottles.

In the smaller types the vessels fill as quickly as they can be handled, whilst in the larger ones they fill as fast as the filling hole will allow.

Mr. **Reynard** asked as to the degree of accuracy of an automatic filling machine. Could a 56 lb. tin be filled to within one-eighth of an ounce? Without such accuracy the machines could not be used for dealing with certain substances owing to their cost.

Mr. F. H. **Alcock** pointed out that in emulsion mixtures the oils separated, and he desired to know what provision was made to ensure, in the filling process, that the whole of the product, and not a portion, found its way into the receptacle to be filled.

Mr. **Broadhurst** said they did not like dealing with liquids containing sediment, but a machine could be fitted with an agitator to keep the content stirred. The chief guard against sediment was a small store tank that emptied every few minutes with a running machine. There was then no chance for the sediment to settle. Tins of 1 lb. and 2 lb. on the ordinary levertop machine could be filled at the rate of 25 per minute. The 5 and 10 galls. machines were capable of dealing with 5 tons of liquid per hour.

Mr. H. C. Marris asked if there were any automatic machines which would fill a cask full and state what the weight was irrespective of the size of the cask?

Mr. Broadhurst: I regret it has not been developed to that extent yet.

To the contributors of papers a hearty vote of thanks was passed.

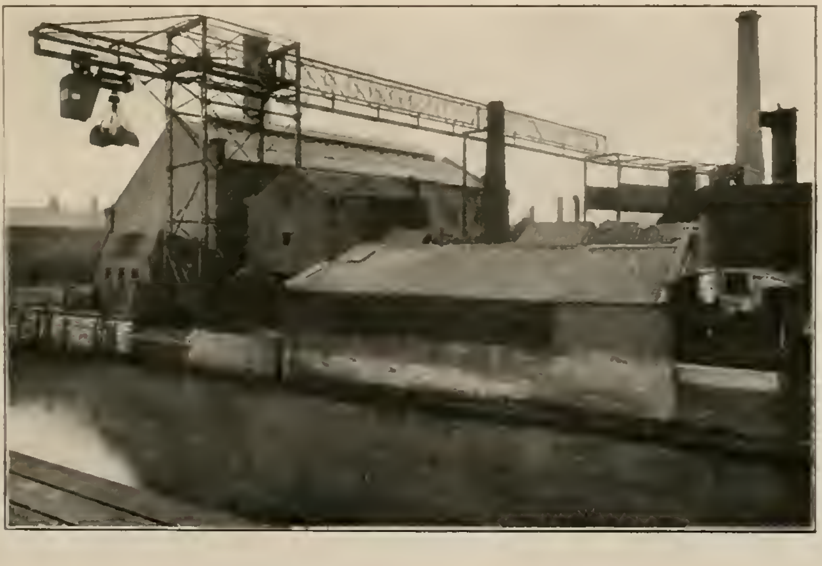
MODERN HIGH SPEED ELECTRIC TELPHERAGE, AND ITS APPLICATIONS IN CHEMICAL WORKS.

BY H. BLYTH, A.M.I.MECH.E., A.M.INST.C.E.

In all branches of industry there is a necessity to-day for doing everything at high speed and with the greatest all-round economy.

This call for speed of course proceeds from the demand for increased output within a shorter time, and, in passing, it should be noted that the 47 hour week means a loss of output of 11½% and the proposed 44 hour week would mean a loss of over 17% as compared with the production of the 53 hour week.

Now unless the old methods of production are greatly improved to enable every man to do at least 11½% more work under the new order of things as he did under the old, it is clear that we are going to be short of every kind of commodity, and when we consider also that wages have advanced more than 100%, it is perfectly hopeless to imagine that prices can ever approach to a pre-war level unless we can raise our output to something like 123%. At present this seems quite impossible of achievement. Some new inventions are wanted, or, alternatively, some of the old ideas must be polished up and made very much more efficient.



It will also be readily seen that the means of handling goods and material has a direct relation to the output from any given factory, and one of the most important items in the selling cost of any particular commodity is the handling cost of raw material and finished product.

In considering the handling problems of any given works, questions other than cost have also to be taken into account—the nature of the material, established conditions of the site, convenience, depreciation and maintenance of the proposed plant, running cost of the plant, have all to be thought of before a proper decision can be arrived at.

This thought introduces my subject of electric telpherage. The Telpher is a particularly convenient and simple machine for conveying any class of goods or materials over a moderate distance with a minimum consumption of power and at a low maintenance cost. This system was invented in the year 1882, 38 years ago, by Professor Fleeming Jenkin, an eminent electrical engineer who began his practical career in Manchester.

A Telpher Company was formed in 1883, and one of the first Telpher lines to be erected was at Weston, in Hertfordshire. It was 700 feet long, consisted of round iron rods and carried a total rolling load of 1 ton at a speed of 5 miles per hour.

Passing over the early operations of this first Telpher Company, I cannot trace that any real attempt was made to put telpherage upon a practical commercial footing in this country until about 1903, when Messrs. Siemens Bros., having obtained information of Telpher practice in the United States, began the development of this conveying system at Woolwich, and later continued it at Stafford for a time.

Some of the plants installed by Messrs. Siemens may be seen at:—

- The Associated Portland Cement Co.'s Works, Gravesend.
- Peases' West Colliery, Crook, Durham.
- Cape Copper Co.'s Works, Swansea.
- Newport Gas Works.

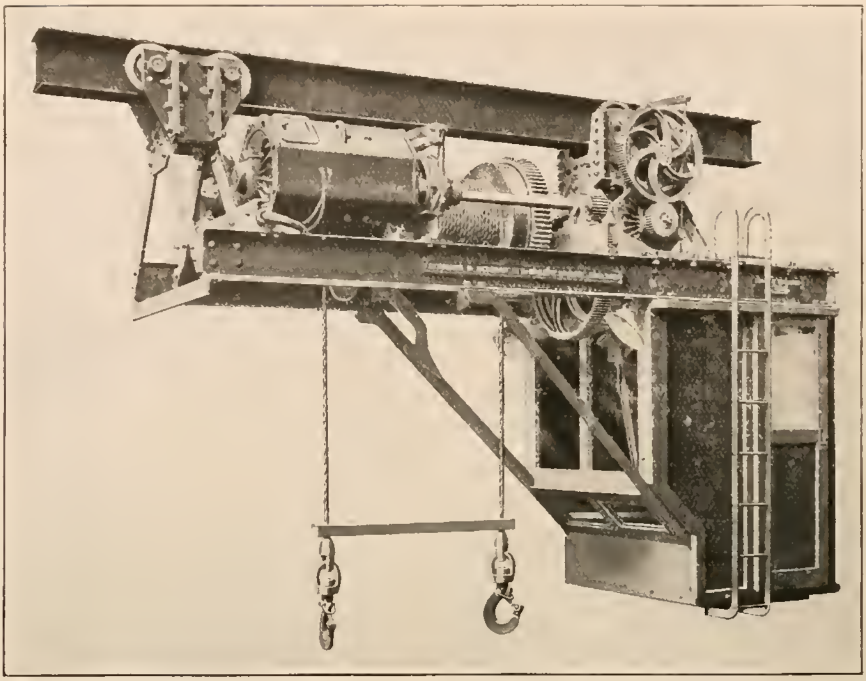


Fig. 3.

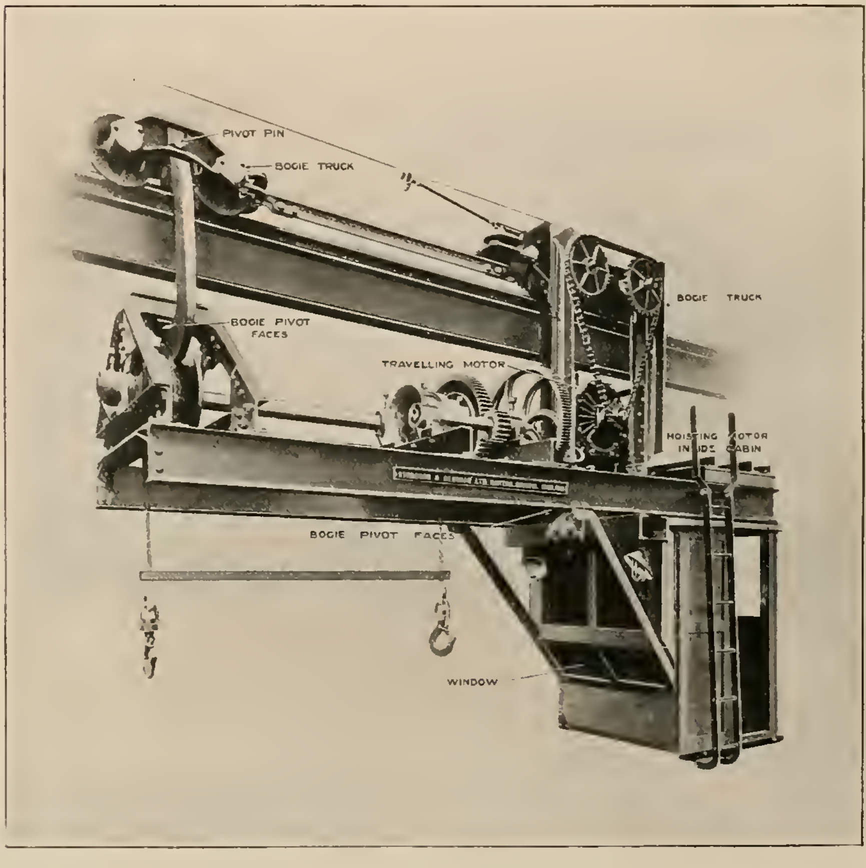

PIVOT PIN
BOGIE TRUCK
BOGIE TRUCK
BOGIE PIVOT FACES
TRAVELLING MOTOR
HOISTING MOTOR INSIDE CABIN
BOGIE PIVOT FACES
WINDOW

Fig. 4.

Later on Messrs. Siemens handed the Telpher business over to Messrs. Strachan and Henshaw. Progress has also been made with telpherage in Germany, but upon rather different lines, and I think you will be interested to learn (unless you are already aware of the fact) that most of the larger chemical works in Germany use telpherage for unloading from barges and railway trucks exclusively.

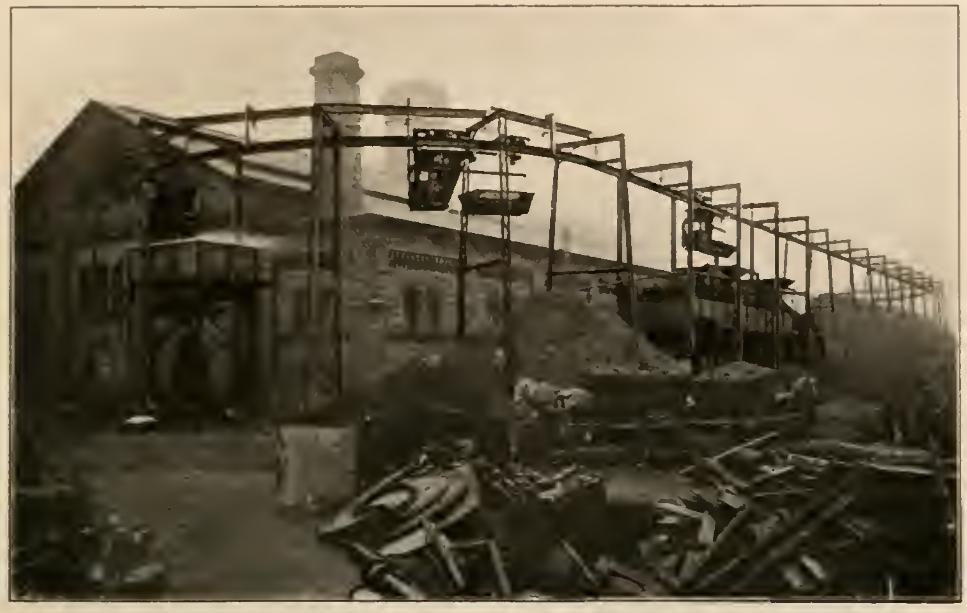


Fig. 5.

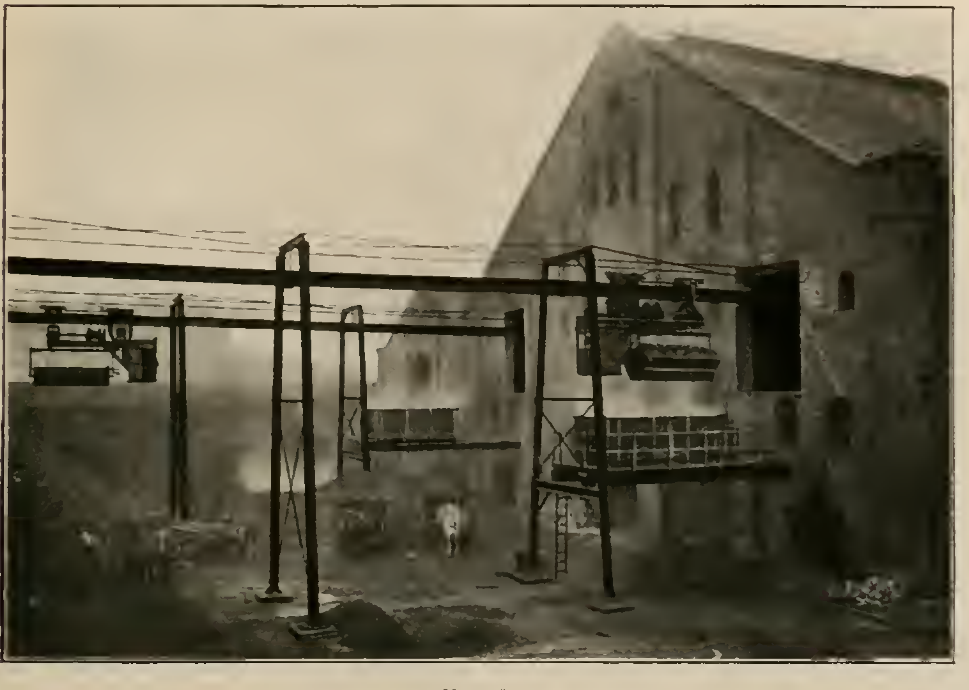


Fig. 6.

For example, Frederick Bayer and Co., at Leverkusen, use Telphers for unloading salt, sodium nitrate, coal, pyrites, etc., from barges and conveying to storage; also for transmission from storage to various parts of the works.

Again, at the superphosphate works of H. and E. Albert, Biebrich, making 80,000 tons superphosphate per annum, Telphers are used for unloading raw materials from trucks and conveying to the stores and mills; also for bringing materials to the mixing points and handling the finished product.

Telphers are also used at the Knapsack Calcium Carbide Works near Cologne.

Some of the latest applications of electric telpherage in this country are to be seen at Plymouth Gas Works, from which, in addition to gas and coke, there is a large output of chemical products; Nobel's Works, Pembrey, near Swansea; The Gas Works at Woolwich Arsenal, where there are eight Telphers, each of 50 cwt. capacity, and about half a mile of track. At Wolverhampton—the electricity works and also at the gas works; also at Widnes, Warrington, Liverpool, Manchester, Glasgow, Hull, Dundee, etc., etc.

The modern Telpher is quite different in principle from the more generally known type of transporter which operates upon the bottom flange of an " H " beam.

On reference to figures 1 and 2 the distinction between the bottom flange transporter and the telpherage, or top rail, system will be clearly seen.

Fig. 1 shows the cross section of a typical wheel carriage of a bottom flange transporter. The running wheels are of necessity mounted upon " cantilevered " pins which are in " single shear." and further, owing to the duplex nature of the track formed by the lower flange of the " H girder," there is considerable wear and tear at curves, which is not only detrimental to the girder, but also to the wheels. The method of suspending the track should also be noticed. The connexion is necessarily in tension.

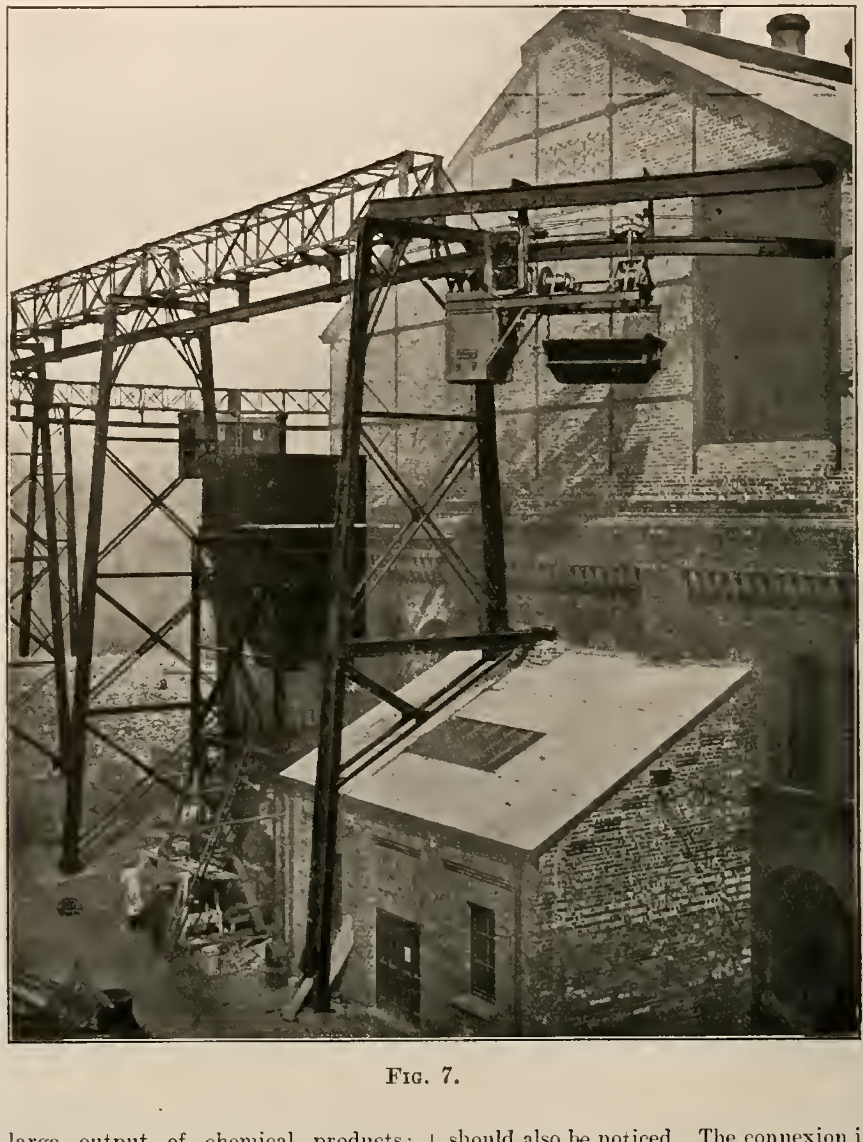


FIG. 7.

Fig. 2 shows the cross section of the modern Telpher carriage, the wheels running upon a single renewable bulb rail which is clipped to the top of the track girder. The whole of the rolling load must, therefore, be perfectly balanced about the vertical centre line, and this arrangement makes it possible to attain a very high speed with safety and steadiness. The wheels are keyed to the axles, which are mounted as " beams " above the track, being, of course, in " double shear." It will be seen that the sizes of the axles and bearings are not restricted, as is necessarily the case in the bottom flange system.

Figs. 3 and 4 show modern machines of the bottom flange and top rail (Telpher) systems respectively. With the Telpher system it is possible to negotiate curves of very small radius; for example, at Southampton Gas Works a Telpher machine weighing 3 tons, carrying a load of 2½ tons (total 5½ tons), traverses a curve of 9 feet 6 inches radius with perfect ease. Radii of 15 feet and 18 feet are common in gas works, where the space is often restricted, although larger radii are, of course, preferable where space permits.

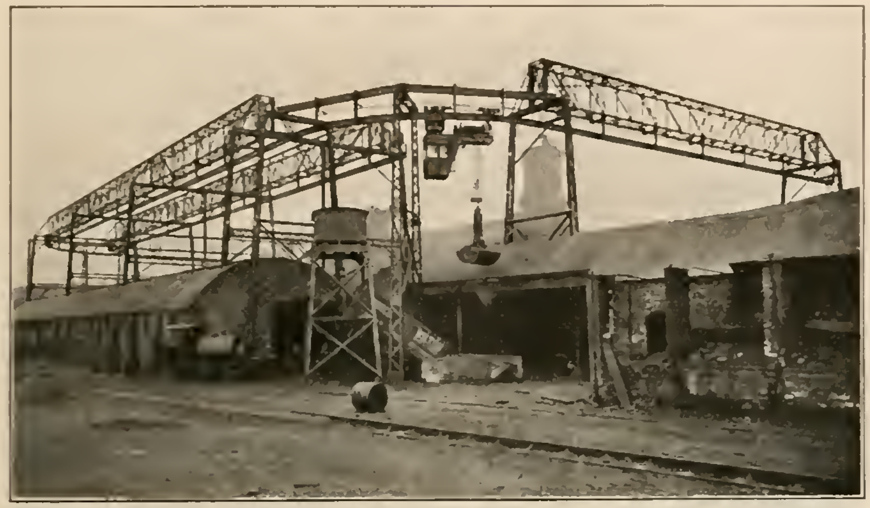


Fig. 8.

Telpherage in gas and electricity works.

Telpherage has been very extensively adopted in gas works for handling coke and other materials, and also in electricity works for coal and ashes.

Illustrations 5, 6 and 7 show the Telpher removing incandescent coke from a retort house. The coke is pushed out of the retorts into skips placed in readiness on the floor, then conveyed to the quenching tank outside the house, the skip is lowered into water, or under an automatic spray, and then relifted and conveyed to the coke yard or storage hoppers and tipped. The photographs are taken from the installations in Birmingham and Wolverhampton.

Illustrations 8, 9, 10, and 11 show the Telpher system as it has been applied to the handling of coal. Fig. 8 shows the Telpher with a 20 cwt. grab lifting coal from the pit into which the railway trucks are tipped. The coal in this case had to be distributed in large quantities to several covered stores. The Telpher can be used to lift sections of the roof at points where it is required to deposit the coal, and after the store has been filled up at any particular point, the roof can be replaced and secured. Fig. 9 shows the Telpher and grab—25 tons per hour can be handled by this machine, lifting through 40 feet and travelling 300 feet each way; the guaranteed handling cost was 1s. 4d. per ton (pre-war), the lifting motor is 14 h.p., and the travel motor 10 h.p.

Fig. 10 illustrates a coal Telpher, fed by crane, at Stepney Electricity Works. It was not permissible in this case to have the Telpher structure overhanging the barge, and a 3-motion crane had to be used to transfer the coal from the barge—first to the hopper of the automatic weighing machine, which in turn discharged the coal to the bunker which feeds the Telpher skip.

The supply of coal is kept up in the bunker, and the Telpher operator lowers his skip in front of the automatic shoot; the skip is filled in about 10 seconds (2 tons of coal), lifted 40 feet and carried a maximum distance of about 300 feet. The capacity (guaranteed) of the plant was 10 tons per hour, but in an emergency 70 tons per hour have been handled.

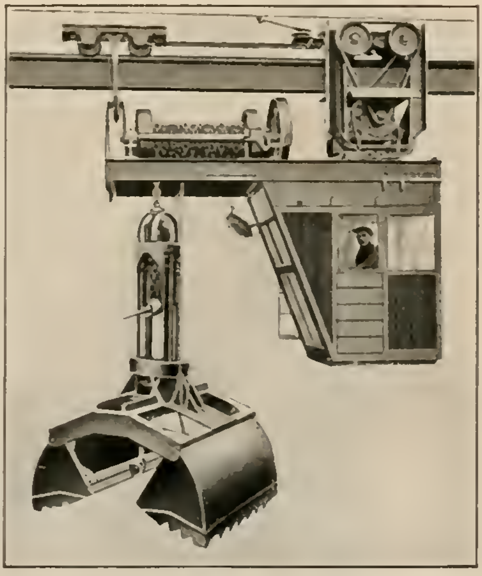


Fig. 9.

Fig. 11 shows an automatic track weighing machine as used for weighing and automatically recording the quantity of coal carried by the Telpher.

A piece of the track is freely suspended independently of the approaches on either side, and this free beam is supported by the levers of the weighing machine. By means of adjustable weights the load of the beam and empty Telpher is balanced so that the weighing is recorded on the totaliser, unless coal is carried in the grab. The weighing in transit by this means is accurate within about ½% (1 cwt. in 10 tons). If the weighing rail is made about 25 to 30 feet long, and hinged approaches are fitted at each end, it is not necessary to stop the Telpher on the beam for weighing.

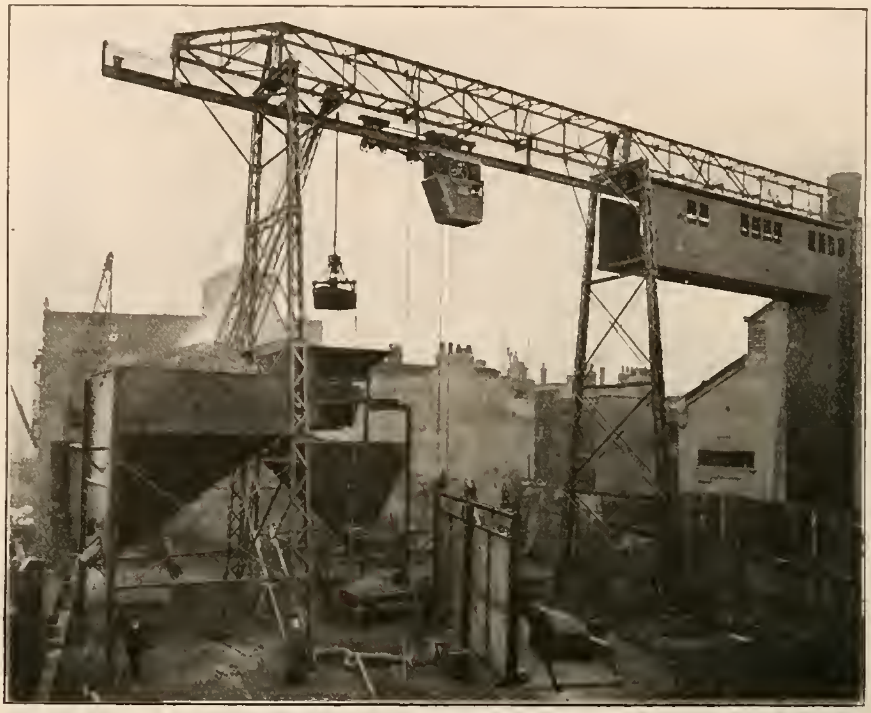


Fig. 10.

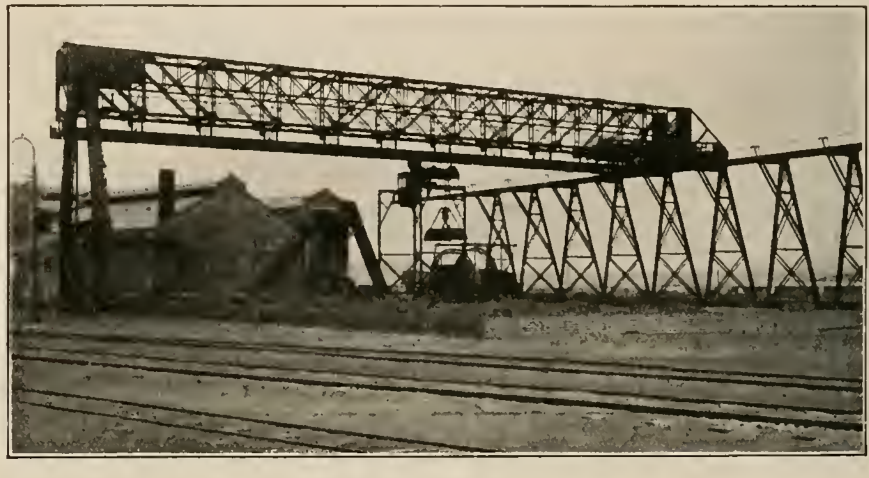


Fig. 12.

The distribution of material from rail to open store ground and reconveying from store to factory is a problem which, until quite recently, presented some difficulty, but the Telpher has been able to solve it, as may be seen at Pembrey, near Swansea.

In 1916 Messrs. Nobel's required to unload coal from 10-ton wagons and store it evenly over an area 350 feet by 136 feet by 10 feet deep, and it was necessary to provide for a storage of 12,000 tons.

The arrangement adopted will be easily understood by reference to Figs. 12, 13, and 14. General description of this plant was published in "Engineering" on July 11, 1919, and therefore for the purpose of this paper a brief reference to the chief points will suffice.

Modern high-speed electric telpherage.

The coal trucks are emptied by a Fraser and Chalmers tipper, at the rate of 8 to 10 per hour, into a pit which has a partition at a depth of 15 feet and a chamber 7 feet deep below this partition. Coal can be lifted by the Telpher and grab from the upper portion of the pit at the rate of 40 to 50 tons per hour and conveyed to store, and simultaneously conducted at about the same rate by means of a rotary feed table, below the partitions, to an elevator, and thence to a band conveyed to the boiler-house bunkers. The special feature of the Telpher installation lies in the fact that the track itself was made to travel the full length of the store ground, and by means of a running switch maintains contact with the fixed track leading to the grabbing pit. The Telpher machine can thus lift the coal from the pit and convey it direct to any part of the store ground, and similarly pick up from any point of the store and carry it back to the pit for feeding the elevator and conveyor for the boiler house. It was not possible in this case to run the track through to the boiler house, as the structure for the latter had already been determined when the Telpher was ordered for the store.

The Telpher has a lifting motor of 20 h.p. and a travel motor of 8 h.p., the current consumption per hour being 6 units—that is, ·15 unit per ton.

The present-day labour cost would be ⅜d. to ½d. per ton.

The elevator is driven by a 10 h.p. motor, and the band conveyor 5 h.p.; total consumption, 11 units per hour.

When considering the maintenance cost of any form of conveyor the fixed ratio (live machinery)/(structure) should be taken into account.

Machinery, generally, is much more difficult and costly to maintain than structure, the rates of cost being about 12½% per annum for machinery to about 2½% for structure, or 5 to 1.

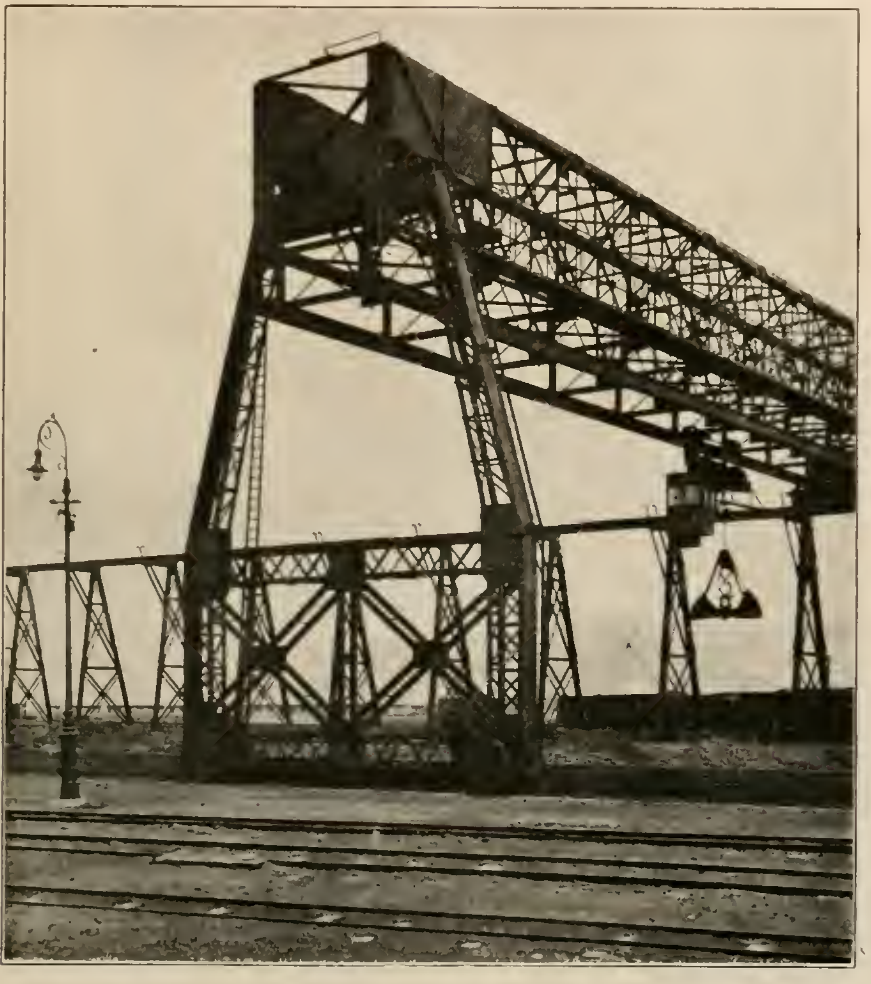


Fig. 13.

Therefore, in deciding between a Telpher plant which has a (machinery)/(structure) ration of about 4 to 1, and a conveyor scheme, in which the value of wearing parts is about equal to that of the fixed structure, careful consideration has to be given to this question of comparative depreciation. If the relative depreciation is worked out in this ratio of machinery to structure, it will be found that an average charge of 4½% per annum covers the

Telpher installation, and 7½% covers the conveyor installation of the same capital value, that is assuming the 12½% for machinery and 2½% for structural work.

Labour element.

It is often claimed on behalf of most conveyors of the chain or bucket type that they "run by themselves" without attendance, whereas the transporter necessarily requires an operator always.

This is not a true representation of the case.

Transporters of the heavy type suitable for handling general goods and coal and coke at a high speed, of course, require a driver, but the operation is simple, and the machine generally requires very little attention and is easily kept in running order.

Now, a conveyor, although it nominally runs without attention, has to be watched at the delivery end; the delivery point has to be changed by hand adjustment; it has innumerable wearing parts, visible and invisible, which have to be inspected by a skilled man. To do the same duty as a transporter an elevator is required to lift the load and deliver it to the conveyor, unless the difference in level is very small, necessitating only an incline in the conveyor.

The liability of stoppage and consequent loss due to breakdown are naturally much greater in the conveyor than in a modern transporter or Telpher.

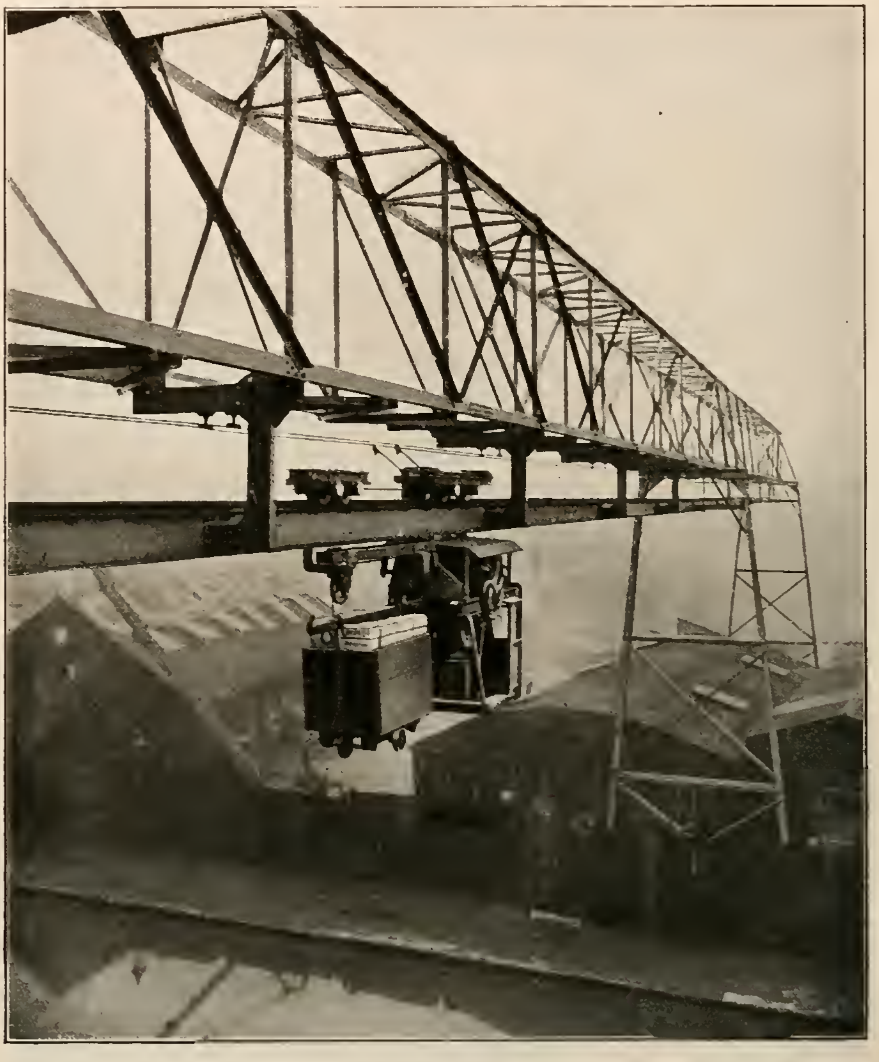


Fig. 15.

A conveyor will not—without auxiliary plant or labour—rehandle material which it has once dumped, whereas a grab Telpher will pick up at any point as easily as dump at any point.

Therefore, in considering the labour element, all these points must be brought into account to make a true comparison.

Capital.

In considering the amount of capital that can be safely spent on any scheme, the number of men to be saved should first be determined, and then the capital per man calculated as follows:—

Depreciation—say 4½ or 5% for a Telpher plant.

Maintenance cost—say 3%.

Interest to be paid on capital, having regard to the fact that the 5% of the capital sum is paid off each year by the depreciation fund. At the end of the first year 6% has to be provided on the full capital sum, on the last year the last instalment is written off, hence an average capital charge of 3 should be allowed for.

We thus arrive at a total annual charge of 11%.

Taking a man's wages at £3 per week—£156 per annum—and capitalising this on the 11% basis, we get £1,400 as the capital equivalent of one man, so that if the cost of the scheme divided by the number of men saved is greater than £1,400, it will not show a financial advantage; on the other hand, if it is less than £1,400, it will show a saving.

Figs. 15 and 16 show Telpher installations at two London factories. It would seem that such conveying plant—with suitable modifications to meet particular requirements—could be applied to the chemical works in this country with very considerable advantage.

At the present moment several such schemes for unloading and storage of material at chemical works are under consideration.

DISCUSSION.

Mr. S. J. TUNGAY asked for information regarding mechanical efficiency. He took the view that 4½% for depreciation was inadequate. It was suggested that the liability of stoppage, due to breakdown, was greater in a conveyor than in a Telpher, but it occurred to him that repair work in the latter would be the more expensive by reason of the more complicated mechanism.

Mr. BLYTH said in his judgment an allowance of 12½ on machinery was fair, but perhaps 2½% for structural work was rather low. He felt that an additional 1% would meet the case. In such an assembly there should be no difficulty in getting reliable opinions as to what was a fair figure for structure, in which event the point raised would be settled.

Mr. TUNGAY stated that the percentage given for structural work was low for chemical works.

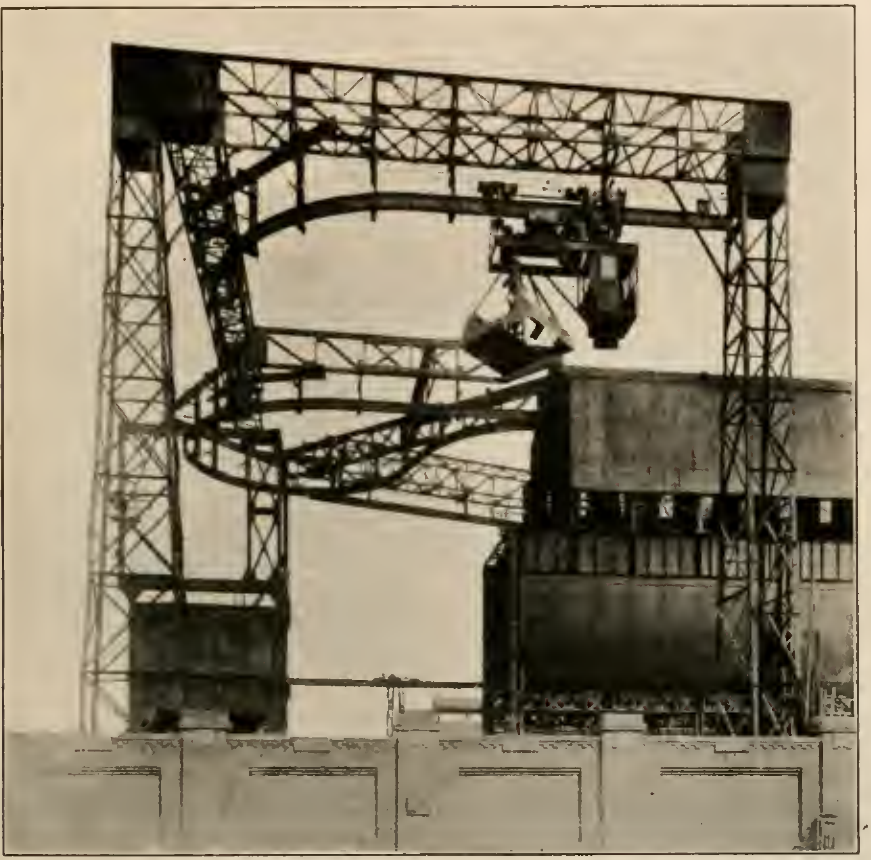


FIG. 16.

Mr. BLYTH replied that more would have to be done in maintenance. The cost of repairing structure was practically the cost of painting it, and 30s. per ton for painting was a fair figure; 12½% for machinery depreciation was on the right side; it had a life of 8 years or rather less, but many cases could be cited of machinery having lasted 10 or 12 years. The whole question lay in that of structure. Repair work in a Telpher was not more troublesome than that in an elevator and conveyor of the bucket or chain type. Eight years ago a chain conveyor was installed at Plymouth for handling coke; that had been taken out and the Telpher was taking its place. A conveyor would run for years, without any particular attention, if it was dealing with dry coal, sand, or grain, where harm was not occasioned to the conveyor parts. Obviously the circumstances of each case had to be taken into account.

PNEUMATIC CONVEYING OF GRANULAR SUBSTANCES, INCLUDING CHEMICALS.

BY GORDON S. LAYTON.

Like many other things, pneumatic conveying was originally discovered in this country, was neglected, and was finally taken up and improved upon by Germany.

It is now recognised that the pneumatic conveyor is not suitable for all circumstances, and that under certain conditions it will not compete with the well-known band conveyors and bucket elevators. Where it is a question of conveying or elevating material from one definite point to another definite point, then, under ordinary circumstances, the lower power consumption of bands and elevators gives them a decided advantage; but where the material has to be gathered from a large area, as, for example, the hold of a ship or a storage floor, then the wages cost in bringing the material to a bucket elevator far outweighs the saving in power, and the fact that the suction nozzle of a pneumatic plant can be brought to the material with little or no difficulty, results in such a reduction in the wages bill as more than pays for the extra power consumption.

Further, when it is necessary to convey material across obstacles, such as streets, railways, rivers, etc., the pneumatic conveyor offers great advantages owing to the ease with which a pipe-line can be erected and supported.

The ratio of the average capacity to the maximum or nominal capacity is considerably higher with the pneumatic conveyor than with the bucket elevator. Thus, with 100 tons per hour maximum capacity in each case, the pneumatic conveyor will unload a cargo at an average overall rate of 70—75 tons per hour, while the bucket elevator will not exceed 55—60.

This point is of great importance for water-borne materials, as it cuts down the time of unloading and therefore reduces demurrage.

Other advantages are to be found in dustless working, greater independence of labour and independence of weather and tide conditions.

When the penumatic conveyor was first introduced it was apparently considered that a solid core of material would be carried along the pipe, either by suction or by pressure; the result of trying to attain this idea was that the power consumption of the early plants was very high indeed. Later on, the Germans showed that this idea was quite incorrect and that much greater efficiency could be obtained by conveying a comparatively small core of material in a large stream of air. The conveying is effected through friction between the air and the skin of particles conveyed, and this friction results in an expansion of the air.

For exhausting the air it is usual to use either piston pumps or blowers. The latter may be either of the Roots type or of the newer turbo-exhauster type. The Roots blower is considerably the cheapest in first cost, but unfortunately its efficiency falls off very rapidly when approaching the vacuum at which nearly all conveying plants are designed to work. It is, therefore, very wasteful in power as compared with the amount of material conveyed.

As regards the turbo-exhauster, this machine has only been developed recently, and in its present form suffers from the same fault at the Roots blower, but in a much milder degree. In our opinion neither of these machines is as suitable as the piston pump, except perhaps in the case of very small plants.

The pump used for pneumatic conveying is quite different from the ordinary type of vacuum pump, the requirement being to displace a large volume of air at comparatively low vacuum rather than a small volume of air at a high vacuum.

As all granular materials contain greater or smaller quantities of some kind of dust, and as it is almost impossible to separate literally all this dust from the air before the entry of the latter into the pump, it is necessary that the piston and cylinder of the pump shall be so designed that the presence of dust in the air will not result in undue wear of the walls of the cylinder; as the dust would combine with any lubricating oil and form an exceedingly abrasive compound, it is necessary that the lubrication of the piston ring shall be effected without the use of oil; this result is achieved by the use of graphite plugs in the piston ring and in various other ways.

Seeing that the pump is called upon to handle large volumes of air, the design of the valves and the provision of easy inlet and outlet passages is a matter of great importance.

With the above exceptions, the design of the vacuum pump does not differ from that of any good reciprocating engine.

As already stated, all granular substances are accompanied by varying amounts of dust, and it is necessary to separate more or less of this dust from the air before its entry into the pump. There are two usual methods of effecting this:—Firstly, a cyclone of the well-known type placed inside the receiving vessel, and, secondly, filters containing tubes of closely woven fabric; the air passes through the walls of these tubes, depositing the dust on the inner surface.

The advantages of the cyclone are that it offers little or no resistance to the passage of the air; that it never requires cleaning; and that it is cheaper in first cost than the filter. It is, however, generally impracticable to provide a cyclone of sufficient dimensions to separate all the dust from the air, and, consequently, a considerable amount of the finer particles are discharged through the pump. Under certain conditions this dusty discharge may be objectionable, and, further, there is the loss of weight in the material conveyed to be considered; the latter point is frequently of great importance in a flour mill.

The filter consists of a number of tubes of closely woven fabric arranged inside a steel vessel; the air passing from the inside through the fabric, deposits practically all the dust on the inner surface of these tubes. After a time the accumulation of dust results in a considerable resistance to the passage of the air and it becomes necessary to clean the tubes. This is generally effected by means of a shaking mechanism which agitates the tubes, causing the adhering particles of dust to fall off.

However, it is found to be necessary to stop the flow of air through the tubes while the cleaning operation is being effected; and, therefore, in order to avoid interruption in the working of the plant, it is usual to provide two filters, which are generally running in parallel. When cleaning becomes necessary one filter is shut off temporarily from the system by means of valves.

The use of tubular filters enables all the dust to be removed from the air, with the result that the discharge from the pump is quite clean and inoffensive, and, further, the gross weight of all the material transported can be accounted for; but, as already stated, a properly designed set of filters is rather expensive.

In the case of large plants it is impracticable to supply a battery of filters of sufficient size, and there is, therefore, no alternative to the use of a cyclone.

The discharger is the apparatus which passes the material which is being conveyed into the pneumatic plant, while preventing the entry of atmospheric air into the receiving vessel.

There are two types of dischargers in use:—

The first consists of a large steel box divided by a vertical partition into two compartments. This box is arranged to oscillate about a horizontal axis, so that each compartment alternately is brought under the lower opening of the receiving vessel.

The other type of discharger consists of a bucket wheel rotating continuously inside a closely fitting casing. The material which is being conveyed falls into the pockets of the bucket wheel when these are on the top of their revolution, and is passed out through an opening in the lower side of the casing.

It will be obvious that the working of both types is liable to be interrupted by the jamming of a foreign body, such as a piece of wood or a bolt, in the working parts; in each case special mechanism for driving the discharger has been devised to avoid the interruption resulting from such blocking and to enable the discharger to keep on working continuously.

The rotary type of discharger is preferable to the tipping box type, for the following reasons:—

1. That the discharge takes the form of a practically continuous stream, while that of the tipping box occurs as large isolated masses of material.
2. That it is more easily kept air-tight.
3. That it works without any vibration.

The design of the transport line is one of the most important points in a pneumatic conveying plant. The chief advantage of the pneumatic conveyor over other methods of handling material in bulk, lies in the fact that it is possible to take the nozzle to the material instead of *vice versâ*; but in order to work the plant to the highest efficiency it is necessary to keep the transport lines as straight as possible, as bends hinder the flow of the material along the pipe, and, therefore, result in an increase in the power consumption.

In some plants a flexible hose is used to bring the nozzle to the point of working, but as its very name implies, flexible hose involves bends, and its use should therefore be avoided as far as possible.

In a well-designed plant, joints of various types are used, by means of which the transport line can be moved as a whole, either horizontally or vertically, so as to enable the nozzle to reach a large surface of the material which is being transported, while still retaining a straight transport line.

This point is exceedingly important, as the falling off in the capacity resulting from bends in the line is very marked; of course, the use of flexible hoses cannot be dispensed with entirely, but the extra cost of the joints in the transport line necessary to provide a wide range of movement is amply repaid.

The passage of the material along the transport line results in a certain amount of wear taking place at the bends; and especially on that wall of the pipe which forms the outer radius of a bend.

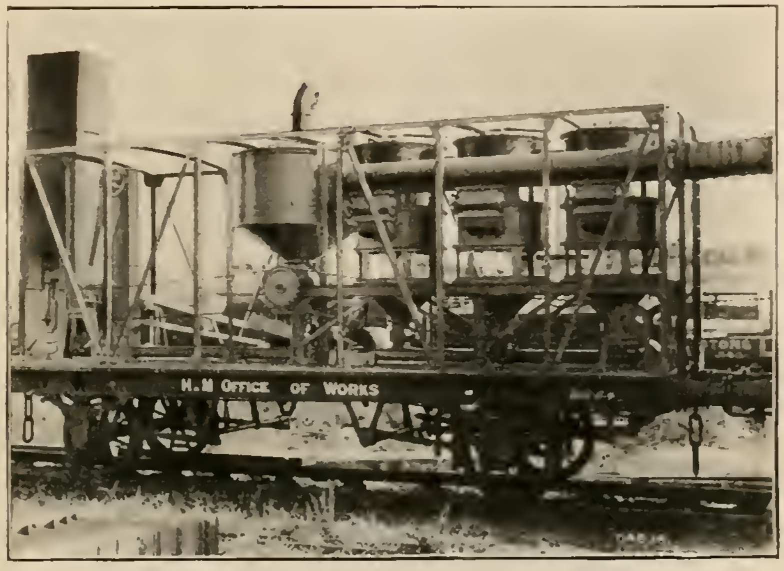


FIG. 1.
Portable Pneumatic Conveying Plant.

In the case of large plants, the bends are usually so constructed that the side of the pipe forming the outer radius of a bend can be readily renewed.

At first sight it would appear that the success of a plant depends very largely on the form of nozzle, and, indeed, more patents have been taken out for improved types of nozzles than for any other detail in a pneumatic conveyor.

As a matter of fact, most authorities have now come to the conclusion that with a freely running substance, such as grain, there is very little to choose between several simple forms of nozzle, and that any complicated design of special air inlets merely increases the price, without having any effect on the capacity; special forms of nozzle, however, may be used with advantage in awkward positions such as corners of a ship's hold, or for dealing with special materials such as cotton seed, damp coal dust, cement, etc., which have a very steep angle of repose.

The other details forming a pneumatic plant, such as the flexible hose, couplings for connecting together lengths of the pipe, and the air-line connecting the receiving vessel to the pump, do not call for any special remarks.

Most of our experience with pneumatic conveyors has been gained when handling grain, but it is quite obvious that many other granular substances can be conveyed with equal success. Such heavy bodies as chain slings, wire ropes, spanners and pieces of wood, have been found in grain which has been unloaded from ships by pneumatic conveyors.

It has long been known that small coal and coal-dust could be handled successfully, and we have in hand at present plants for conveying dry salt, sugar, powdered charcoal, superphosphates in their raw state, and cotton seed, which last is a very difficult material to convey owing to its clinging nature.

A properly designed plant will leave no harmful effect upon the material which has been conveyed; thus, for reasons which need not be entered into now, it is necessary when handling malting barley that the outer husk should not be removed. With many classes of barley this outer husk is very tender, yet with due attention to the air speeds in the transport line, even the most tender barleys can be conveyed without damage. We think, therefore, that there need be no fear that any ordinary material would suffer from being conveyed by pneumatic means.

The most usual form of plant is the suction type, in which the direction of working is, in accordance with the flow of air, inward toward the centre; the working, can, however, be reversed, the material being conveyed by blowing out from the centre to one or more points as required. For various reasons it is not usual to construct blowing plants for a large capacity. A difficulty arises in connection with dealing with the dust, as it is obviouly more convenient to do this when the material is being deposited at one centre, than to do so when it is being deposited at a variety of stations.

In general, it may be said that a blowing plant is cheaper in first cost than a suction plant of equal size.

It is very difficult to give details as to the power consumed by a plant, as this depends upon the capacity, the length, and the nature of the transport line, and lastly, upon the nature of the material which is being conveyed.

The usual form of intake line contains a vertical lift of 40 to 50 feet, with a horizontal distance of up to 35 feet. This is the type of plant which is commonly used for unloading ships, the material being deposited just inside the building.

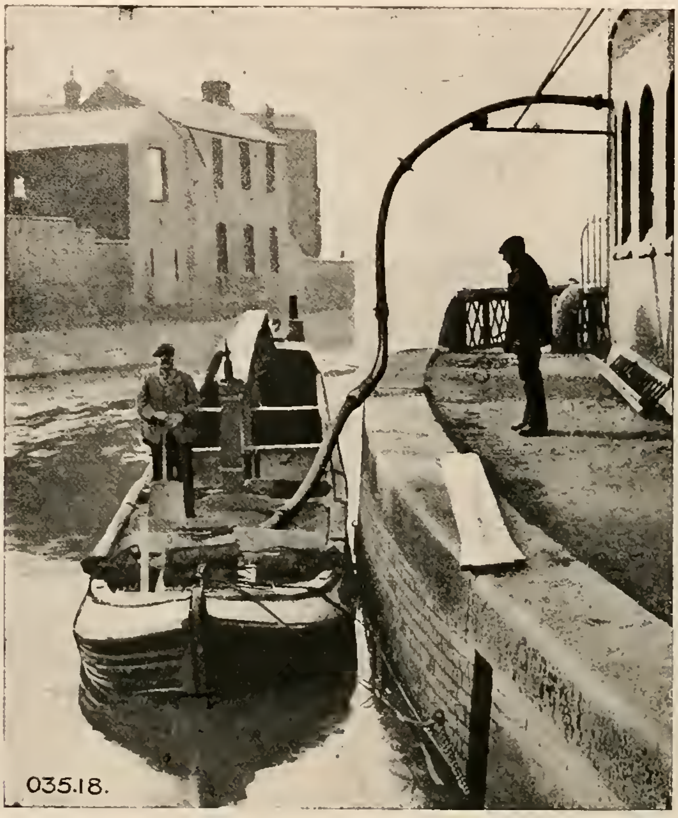


FIG. 2.

Unloading coal by pneumatic conveyor.

When working on wheat with the ordinary type of intake line, the power consumption for plants up to a capacity of about 50 tons per hour may be as low as 1 B.H.P. per ton of material elevated per hour. In the case of larger plants it is generally necessary to use two or more transport lines connected to the same receiving vessel and pumps; owing to the difficulty in keeping two or more nozzles working equally, the power consumption in such a case may rise to 1¼ B.H.P. per ton.

With regard to the power consumed in horizontal conveying, it is even more difficult to give an example; but, assuming that the pipe lines do not contain an excessive number of bends, 1 B.H.P. per ton per hour per 100 feet of distance conveyed may be taken as a maximum.

With regard to the cost of installation, this depends entirely upon the nature of the plant; for example, as already stated, a cyclone may be used in some instances for separating the dust, or the requirements of the site may necessitate the use of the more expensive tubular filters; again, in some plants a rotary blower may be substituted for the more expensive piston pump. But as a very approximate estimate, it may be said that an intake plant with a capacity of 20 tons to 30 tons will cost to-day about £75 per ton of material per hour; while in the case of a large plant of say 200 tons to 250 tons per hour capacity, the above figure would fall to about £50.

Where material is conveyed horizontally, £40 to £50 per ton of material conveyed per 100 feet of distance would be a very approximate cost of installation.

With regard to the cost of working with a pneumatic conveyor as compared with other methods, the following figures were given to us by a firm using one of our plants. Wheat was brought up to the mill in a small vessel containing a little over 200 tons. The previous method of unloading had been by hand at the following cost:—

	£	s.	d.
Dock labourers, bushelling, carrying and weighing at 2s. 6d. per 100 bushels	10	0	0
Three men in mill, 20 hours each at 6d. per hour	1	10	0
	£11	10	0

Equals 13 pence per ton.

When using the pneumatic plant, the cost was as follows:—

	£	s.	d.
Average capacity, 25 tons per hour.			
Two men, each nine hours at 6d. per hour		9	0
Power, 32 h.p., nine hours—220 B.O.T. units at 1d. per unit ...		18	4
	£1	7	4

Equals 1·6 pence per ton.

The cost of the plant was about £600, including erection.

DISCUSSION.

Capt. GOODWIN said the question of the filtration of dust after the material had been conveyed to its destination was most important. Before an efficient method was evolved a great deal of experiment by chemical engineers would be necessary. The dust question constituted the crux of the problem. Earlier in the day bag filters had been recommended as being the best known method. Had the electrostatic deposition of dust been thought of in connection with the plants? He did not think such a plant would be very expensive, and it might be applicable in the case of large installations. It also lent itself in many ways to this particular problem. The difficulty experienced in cleaning bags might, it seemed, be minimised if there were a combined system of cyclones and bag filters, the latter dealing only with the finest particles and the former with the heavy dust. A third possibility included the substitution of a different type of vacuum pump, which was described as the hydro-turbine. What was the degree of wear at the bends, and had the author used acid-resisting iron? The hardness of the latter material had been found to repay the extra cost of it.

Mr. LAYTON, in reply, said as to the question of the separation of dust he did not suppose that the dust which would accompany chemical substances was finer than that generally to be found in grain. This question was raised some time ago with regard to the plant with which he was concerned, and the query was made: "Could we guarantee a dustless discharge?" He accordingly placed a hard felt hat immediately in front of the discharger, kept it there for several minutes, and then took it down, but no dust had been deposited upon it. The result satisfactorily answered the question, and it was obtained with a plant fitted with ordinary tubular valves. The electrostatic method had not been tried, although it had been mentioned as a possibility. Possibly there might be something in it, but upon this point he could not express a definite opinion. With regard to the possibility of using cyclones and filters in conjunction, he pointed out that the filter would separate the finer grain of dust, so that there would be no object in putting in a cyclone in addition. The question of the installation of a water pump had been considered, but not tried. There was apparently this disadvantage that the water would form a sludge of air dust that went along and then its recovery might be an expensive matter. At one time they used a wet filter, and from tests they came to the opinion that under the partial vacuum under which the plants worked that the water partially vaporised. The amount of material conveyed was thus reduced. As to the wear at the bends, and the life at the bend, he pointed out that the supply of a fresh bend was not a serious matter. It was perhaps only £5 on a plant the cost of which might run into most substantial figures. He was unable to give a reply as to what was the effect of erosion by chemicals or acids, but the life of a bend in an ordinary drawn steel pipe would be probably not less than two years.

Capt. GOODWIN: What about coal?

Mr. LAYTON: One would then make special provision for protecting the pipe at a bend. Perhaps a bend might be made of square sections, and these could be of extra thickness and bolted on, so that if a hole appeared it would be merely a question of putting on an extra plate—not a serious matter.

Mr. P. PARRISH said he was convinced that the only economical way in which to deal with a large bulk of material was by means of the railway. He was, however, anxious to know if the author had had any experience in dealing with spent oxide, the character of which differed from the ordinary provincial spent oxide, being very fine. It had been specially prepared and appeared to lend itself admirably to a conveyor. The water content was not large. Provincial spent oxide might be irregular, with a varying degree of moisture from 8% to 20%, while the sulphur content might be from 40% to 65%. It seemed that four points had to be considered in relation to the use of the pneumatic conveyor: (1) that the specific gravity of the material must have an important bearing on the application of the conveyor; (2) the degree of fineness of the material; (3) the moisture content; and (4) the absence of lumps. It occurred to him that spent oxide of the kind mentioned might possibly be dealt with more efficiently and cheaply than by means of the railway. He desired to know also if the author had attempted to interpose in connection with the discharger any type of crusher? And did the drying of material take place to any extent during passage along reasonably long lengths of pipe? It would certainly be an advantage if partial drying took place.

Mr. LAYTON, in reply, pointed out that some classes of grain frequently contained up to 20% of moisture. He did not think that percentages mentioned would offer any insuperable or appreciable difficulty for conveying. As to the question of lumps a homogeneous material was naturally preferred, but within reasonable limits no objection could be raised. The insertion of a crusher into the system before the discharger would mean the enclosing of such an apparatus in an air-tight vessel. That would mean great expense, and the advantage to be derived appeared doubtful. If it were feared that the presence of lumps would interfere with the rotation of the discharge he would point out that a gear might be inserted for reversing in the event of "choking," so that when the bucket wheel became jammed the application of air automatically reversed the direction of rotation, and the bucket proceeded accordingly. As to the partial drying of material he pointed out that the time taken in transit was so small that there could not be any appreciable drying. The speed through the pipes varying from 40 to 50 feet per second, so that if material were conveyed 300 feet the exposure to the air was a matter merely of a few seconds.

Mr. J. A. Reavell inquired if wood chips, dry or wet, had been dealt with in the pneumatic conveyor, also bark from tanneries, heavily saturated with water, and which would sometimes take its own weight in water. Could a wooden delivery trunk be used instead of one of iron? As to the question of dust he had recently been interested in a milk drying plant. The difficulty had been to get a filter that would hold the dried milk. Many filters allowed the powder to pass through, and consequently a financial loss occurred. Milk was too dear to allow of much experimenting in this direction. Was there any ratio in the height of the vertical lift compared with the horizontal length?

Mr. H. C. Marris said it was important to know precisely what a conveyor could do with regard to excessively wet bark from tanneries. The weight of water was frequently greater than the weight of the material itself—up to three quarters.

Mr. Layton said in his opinion no difficulty would be experienced in conveying dry chips, or even wet ones. He had never conveyed material of this class, but knowing what a pneumatic conveyor could do—even to the extent of carrying a $\frac{7}{8}$ spanner—he thought that bark could be effectively dealt with. There seemed no reason why a wood trunk should not be used, though means would have to be taken to prevent air-leakage at the joints. Possibly a trunk could be rendered air-tight by the outside application of finely-painted canvas. Milk powder had not been tried on the filters.

Mr. Tungay asked as to the heaviest specific gravity material that could be lifted by means of the pneumatic conveyor. Possibly the spanners which were taken up were supported by the other material that was passing through. He did not suppose a load of $\frac{7}{8}$ spanners could be conveyed?

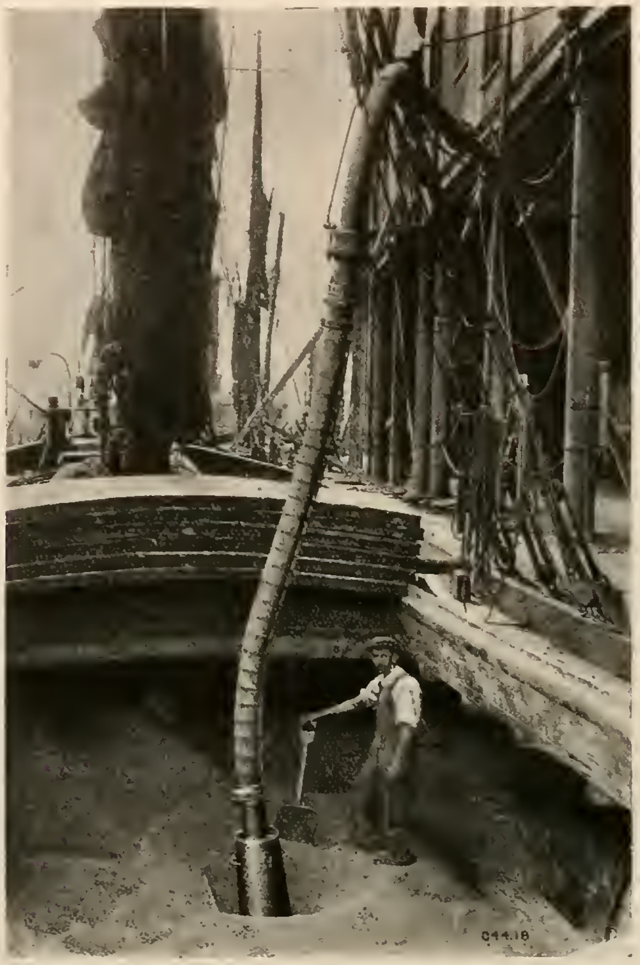


Fig. 3.

Nozzle intake of Pneumatic Conveying Plant.

(Laughter.) He did not think the insertion of crushers would be an impossible matter. What data was available as to the power efficiency?

Mr. LAYTON replied that cement, one of the heaviest of materials, had been successfully conveyed. The question had been asked as to whether materials, such as lumps of high density, was not assisted through the pipes by tho other material. As the percentage of fulness of the pipe was only up to 15 as a maximum it was clear that other materials could not afford much support to such things as lumps or spanners. As to the installation of a crusher before the discharger he pointed out that such would occupy a good deal of space, and would have to be enclosed in an air-tight vessel which would have to bear a big pressure. The expense would be rather considerable. As to the question of increased power consumption on the larger plants the explanation was that with a larger capacity, up to 100 or 300 tons an hour, difficulty was experienced in getting the material through one transport line. Two or more pipes became necessary, and then the difficulty arose of keeping the two pipes balanced. The air tended to follow the path of least resistance. The two increased in Continental chemical works, and particularly in those in which the material was delivered in crystalline form.

Dr. G. S. WALPOLE said he thought we should see the use of the pneumatic pump become universal. It was greatly in vogue on the Continent, and particularly in Germany. In some of the large chemical works whole processes, including that of delivery, were carried out in unbroken continuity. Among the things handled by the pneumatic conveyors were common salt, ammonia, wet wood chips, and glass sand, though with regard to the last-named special protective material was used at the bends of the pipes. Without such material the life of the bends was short. Cyclones and bag filters were used, but he could not speak definitely as to the use of vacuums. In certain cases the steel pipes were lined with wood, and sometimes square wooden channels were employed. The velocity was about 30 feet per second. The pneumatic method of handling had during the past 5 years greatly increased in Continental chemical works, and particularly in those in which the material was delivered in crystalline form.

THE CHAIRMAN: It is unfortunate that in such respects science on the Continent is ahead of us in this country, but we shall have to remedy all that. (Hear, hear.)

In the absence of the receipt of a paper on "The Development and Use of Labour-Saving Devices in the American Chemical Industry," by Mr. A. E. Marshall, of the Davison Chemical Co., Baltimore (as announced),

Mr. S. H. Johnson, of Messrs. W. and T. Avery, Ltd., Birmingham, read a paper on "The Development of Automatic Weighing Machinery and Its Application to the Chemical Industry."

THE DEVELOPMENT OF AUTOMATIC WEIGHING MACHINERY AND ITS APPLICATION TO THE CHEMICAL INDUSTRY.

BY S. H. JOHNSON.

Up to the present automatic weighing machines have been little used in the chemical industry, one reason being the difficulties which chemical products offer to automatic weighing. The war, however, caused rapid developments in automatic weighing machines and the weighing of materials which hitherto had been untouched, such as ammonium nitrate, T.N.T., etc.

The first basic principle of an automatic weighing machine is that it shall be a proper weighing machine developed or constructed on the usual weighing principles as accepted by the Standards Department of the Board of Trade. The second is the automatic action which consists of an arrangement of shoots, inlet valves and outlet valves, suitably controlled by levers and the like, by means of which the material being weighed is caused to flow properly into the weigh hopper and discharged therefrom in the shortest possible time.

Accuracy in weighing is the first essential of an automatic weighing machine. The machine must be accurate to a fine degree, otherwise there is no case for its installation in your plants. The two basic principles described above are really completely independent units but so closely allied and in tune with one another that they function in harmony and thus produce the accurate automatic weighing machine. These units only come actually into contact at the moment of the cut-off of the flow of the materials into the weighing receptacle of the automatic weigher, and then only for the very briefest contact necessary to trip a trigger to cause the closing of the inlet valves. It will be seen from this that the weighing principle of an automatic weigher is a free swinging beam precisely as free as the beam of an ordinary scale.

The automatic weighing machines as made by Avery's are divided into two large classes, viz.:—

(*a*) The even-armed beam automatic scale which weighs off predetermined loads against dead weights.

(*b*) A proportional lever and steelyard machine for automatically weighing and totalising varying weights.

These two classes are again split up into many subsidiary types called for by varying conditions and materials, and have been evolved by experience. The first material which was automatically weighed successfully on the even-armed beam type machine was grain, such as wheat, oats, etc., and this machine achieved immediate success, with the result that there is not a grain intake plant at the docks, or a flour mill, or any other plant where grain is handled, which has not automatic weighers installed.

The first two slides shown illustrate automatic grain weighers in the huge grain silo at the Manchester Ship Canal, Salford Docks. This silo has a storage capacity of 45,000 tons of grain, and is fitted with 12 "Avery" automatic grain scales, each with a weighing capacity of 2 tons per draught of any kind of grain and capable of weighing 150 tons per hour each machine (Fig. 1).

From the automatic weighing of grain evolved the automatic weighing of flour and powdered materials generally. These powdered materials offered great difficulties in the beginning owing to the necessity for the powders to be so controlled that they flowed regularly and freely into the automatic weigher in order to obtain accuracy in weighing. The slide shows the automatic flour and powder weigher. It should be noted that the machine has a drive at the top which controls a power-driven feed apparatus.

The next slide shows a somewhat similar machine but fitted with a different kind of feed apparatus with dust cover entirely protecting the flowing of the material through the automatic weigher and thus obviating dust (Fig. 2). The machine is used extensively in artificial manure works for the weighing of ground phosphate to the mixer before it is treated with sulphuric acid. A number of machines of this type were also used during the war at the Chilwell Shell Filling Factory for the purpose of weighing ammonium nitrate, a material which at that date had somewhat the nature of damp snow and would stick badly. It was weighed on the Avery machines after some experiments with the greatest success. The feed shoots and weigh hoppers had to be bell-bottomed in order to evacuate the material. Tandem machines were supplied, one weighing 4 cwt. of T.N.T. and the other 16 cwt. of ammonium nitrate. The machines were arranged with a simultaneous gear so that they discharged their weighings together to the mixer underneath.

The next slide illustrates a machine still of the powder type fitted with a feed apparatus which was used for weighing T.N.T.

The next slide is also a picture of the powder type of machine but without a weigh hopper; it is fitted with a cradle on which a tin or canister was placed, the mouth of the canister being joined to a holder on the goods end of the weigh beam of the scale to prevent dust. This machine was for the purpose of weighing high explosive.

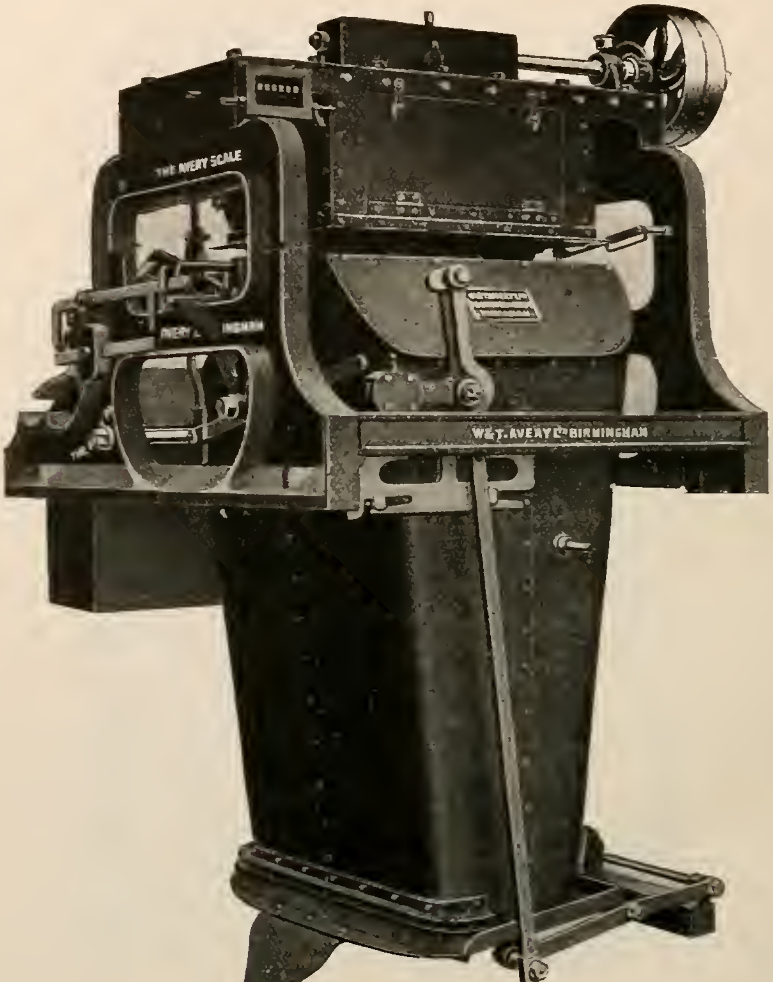


Fig. I.

The next slide shows a machine somewhat similar to the last but is fitted with a sack attached to a bag holder on the end of the scale beam and is for weighing granular materials direct into the sack, weighing the sack together with the material. This machine is also made for the purpose of weighing powders, and is thus fitted with a feed apparatus and a circular feed shoot.

Another important type of the even-armed beam automatic scale is the automatic coal weighing machine. This machine was also an early adaptation of the original automatic grain weigher and is used entensively in power stations etc. The slide shows a machine which is used for weighing coal from the bunkers to the mechanical stokers, the machine having a capacity per weighing of 2 cwt. The machine is made in various capacities up to 3 tons per weighing, which machine is capable of weighing 200 tons per hour of coal. This type of machine weighs small coal only.

The next slide illustrates a boiler house at the Neasden Power Station showing Avery automatic coal weighers feeding coal to the mechanical stokers.

A further and more recent evolution of the even-armed beam scale was the automatic liquid weigher. The machine shown on the slide has a capacity of 1 ton per weighing and weighs any kind of liquid, no matter how thick, as long as it will flow fairly readily. The machine was the outcome of much thought and many experiments and patents, one of the great difficulties being to evolve a feed valve which would shut under pressure without friction and at the same time be perfectly leaktight in order to ensure accuracy in weighing. This valve has been achieved, and from that time may be said to date the success of the Avery patent automatic liquid weigher.

The next slide shows this machine in the top picture (sectional view) receiving liquid into the weigh hopper, and in the bottom view discharging the liquid, which is done by the overturn of the weigh hopper (Figs. 3 and 4). A closed head is provided in the weigh hopper into which a proportion of the liquid rushes and can only escape through a small aperture. This head has the effect of breaking the overrun of the weigh hopper when it tips over, and at the same time by the closing down or enlarging of the aperture keeps the weigh hopper in the overturned position for a long or as short a time as is necessary to enable drainage of the weigh hopper to take place. This machine is constructed in all capacities, and at the present time one is under construction for the British Turbine Makers Associations with a capacity of 2½ tons of water per draught.

We now turn to the second main class of automatic weighing machines as manufactured by Avery's, viz., the proportional lever automatic weigher and totaliser for weighing varying amounts. This machine consists of a power-driven poiseweight running on a steelyard connected up by positive gearing to a weight totalling counter. The steelyard is connected to the usual weighing levers as used on a platform weigher or weighbridge. The slide shows the totalling counter which is registering in tonnes and kilogrammes. For one complete revolution of the dial a further tonne is added to the line of horizontal figures; the weight shown at the moment is 410 tonnes 500 kilogrammes.

The next slide shows one of the machines installed at a gas works in the South of England for weighing coal in tipping trucks on a narrow gauge railway. Each of the empty trucks has to be balanced to the machine and each of the same weight so that the weight indicated on the totalling counter of the machine is the actual net weight of coal.

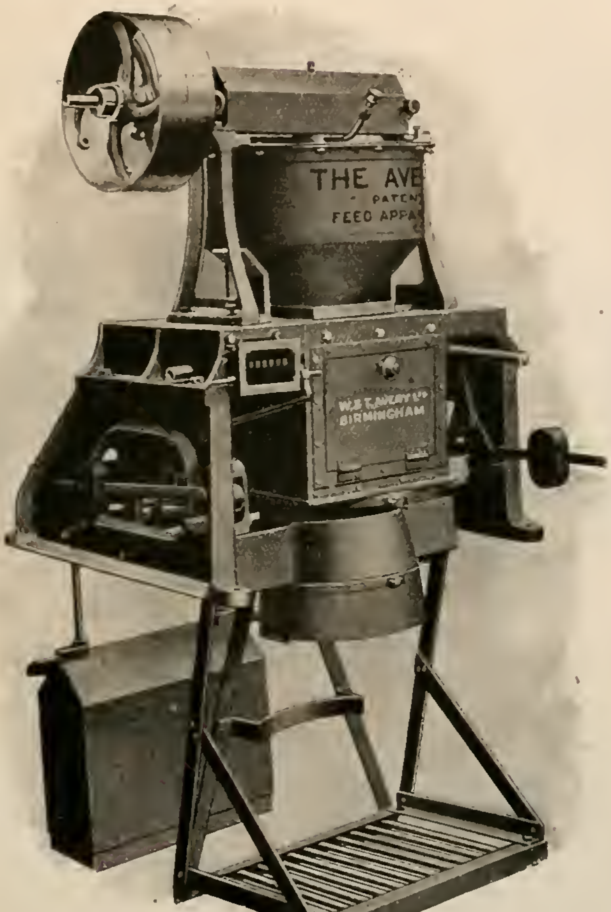


FIG. 2.

The next slide illustrates another type of the totaliser machine, viz., the aerial runway .
A section of the runway is attached by levers to the weighing platform on to which the traveller carrying the loaded skip runs; the skip comes to a standstill for about 10 seconds whilst the net weight of its contents are recorded on the totalling counter. These machines, of course, are applicable for all kinds of aerial runways, transporters, ropeways, etc.

A further type of the totalising machine is the hopper weighers. Suspended on the levers instead of a platform is a weigh hopper. Supported on independent joists over the top of this weigh hopper is a receiving hopper. This machine weighs material discharged by grab, and will handle large pieces such as runs of line coal. The receiving hopper breaks the shock of the falling material from the grab and has no closed end, with the result that the material runs immediately into the weigh hopper and its weight is recorded on the totalling counter of the machine as described before. A time cam then comes into operation and discharges the weigh hopper. The slide shown illustrates one of these machines with a capacity of 1 ton per weighing fitted on to a travelling truck and at work at the Sydney Gas Works for the purpose of weighing coal.

The next slide illustrates a similar machine weighing coal from a grab at Stepney Electricity Works.

The next slide illustrates one of six machines, each with a weighing capacity of 6 or 8 tons of iron ore. These machines are working in the Port of Rotterdam and were installed prior to the war; it should be noted that they are the only British machinery in those huge unloading plants of which they form a portion, the remainder being German.

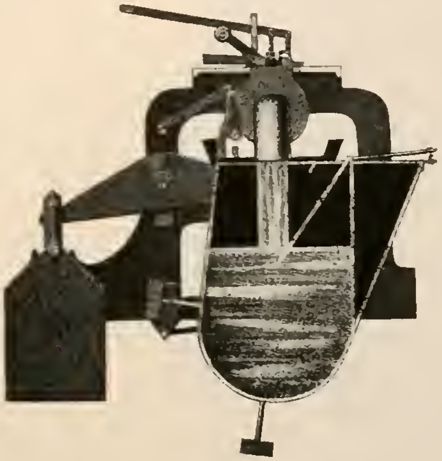


Fig. 3.

The first slide of the two shows the grab open and the iron ore running into the shock-absorbing hopper and so into the weigh hopper on the automatic totaliser, the machine being mounted on a truck to deliver the weighings from the scale either into railway wagon or overside by means of shoots into barge. The second slide shows the grab fully open and empty; the weighing has been recorded and the iron ore is being discharged from the weigh hopper of the automatic scale into railway wagon. It should be noted that in the Totaliser Automatic Weighing Machines a dial which mechanically indicates single loads, or printers which print on a ticket or tape the weight of individual loads, can be fitted.

In conclusion, it is obvious that in modern plants where conveyors, elevators, and other mechanical means of handling are used, the automatic weighing machine is an absolute necessity. It is false economy to instal conveyors and at the weighing breaks in those conveyors bring the entire system to a standstill by weighing by hand. It must be done by automatic weighing machines which will weigh accurately and without stopping the run of the material through your plant. The machines thus are a direct means of plant efficiency and may possibly increase production, with reduced working expenses as compared with the labour necessary for hand weighing.

All Avery automatic weighing machines are fitted with a mechanical counter, also with a weight printer if desired, which accurately record the amount of material weighed.

The **Chairman** observed that with regard to weighing apparatus the name of Avery stood supreme. When a very young man he had the pleasure of making the drawing for the first automatic machine made, designed and patented by Messrs. Avery. He was not certain whether the particular machine was placed on the market, but it was certainly the foundation principle of all the automatic machines that the firm had put on the market.

Mr. H. C. **Reynard** inquired as to the degree of accuracy obtained in the use of the liquid weighing machines with the 1-ton tip, and the number of weighings that could be carried out hourly. In the works in which he was engaged there was a weighing machine fitted with an electric cut-out; it cut out when the receptacle was filled to the necessary point, but as it did not work quite quickly enough rather too much material was allowed to enter the vessel which was being filled. In consequence of this the electric cut-out had been abandoned.

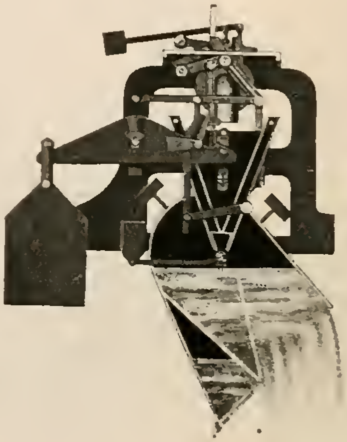


Fig. 4.

Mr. **Johnson** replied that the liquid weigher would weigh to an accuracy of 1 %. Naturally, as the size of the machines was greatly increased the percentage of accuracy slightly decreased. On the one-ton liquid weighers accuracy was assured within 2 lb. The number of tips per hour depended largely upon the character of the liquid that was handled. If it were a free-running liquid a weighing could be obtained every minute: 60 tons per hour. The firm of Avery did not manufacture weighing machines with the electric "cut-out."

Mr. **Parrish** inquired if it were not possible to hang the automatic weighing machine in that portion of an apparatus to which the grab was attached.

Mr. **Johnson** said as a matter of mathematics such an arrangement appeared possible, but in practice it was a failure. The only method of weighing automatically was by an absolutely independent weighing machine—by that he meant a machine independent of any other portion of the plant.

FOURTH CONFERENCE.

FILTRATION.

NEWCASTLE-ON-TYNE, JULY 13, 1920.

The opening meeting of the Chemical Engineering Group was held in the Physics Lecture Theatre, Armstrong College, Newcastle-on-Tyne, on the afternoon of July 13. Professor Henry Louis, D.Sc., presided, and there was a very large attendance.

Professor Henry Louis, in opening, said he was honoured by the request of the committee to preside at the conference of the Chemical Engineering Group, and he had very much pleasure in doing so. He was glad to be able to preface the meeting by congratulating the Chemical Engineering Group upon the very great success it had achieved. Chemical engineering was a new subject. It was a very difficult subject. In many respects it was a subject which involved a certain amount of contradictory qualities in those who were practising it. The true object of the engineer, in the words of the Civil Engineers' Charter, was to utilise the forces of nature for the benefit of mankind. The chemist was occupied in using the materials of nature, and it was the business of the chemical engineer to combine these two somewhat different lines of attack. He thought they were all recognising that chemical engineering involved some of the most complex problems of the day, and one had recently seen in chemical engineering literature what very involved scientific work it implied. He was thinking, as he spoke, of the recent paper of Dr. Sulman on "Flotation." He was able to show that what had been current metallurgical practice for many years depended on advanced theses in chemistry. Applications of that kind would show as chemical engineering developed. The subject they were going to discuss that day was Filtration. He was particularly pleased to preside at that conference because in his address at Bristol some years ago he drew rather particular attention to the need for the study of Filtration, and he ventured to suggest that even to-day chemical engineers had not paid sufficient attention to the need for continuous filtration processes. With the increased cost of labour nowadays one had to make all operations as continuous and as automatic as possible, and that, he suggested, was a point of view the chemical engineer should not lose sight of. The subject of Filtration was, of course, a difficult one, and it might be as well if one cleared one's mind at the outset, and knew exactly what they meant. He did not think it was easy to frame a perfectly satisfactory definition, and probably not all people would agree as to what was really meant. What he understood was the more or less complete separation of solids and liquids by means of a porous septum. He did not know that anything less than that was strictly speaking filtration, and, of course, filtration did not always mean or imply complete separation. In fact, it was quite impossible. They could, of course, get a filtrate that was absolutely free from solid matter, but the other side of the problem was a more difficult one. They had a number of papers dealing with Filtration and closely allied chemical engineering operations, and they would form a complete and continuous series of papers on this subject, which ought to throw a good deal of light on the present condition of the art.

THE FILTRATION OF COLLOIDS.

BY W. R. ORMANDY, D.SC.

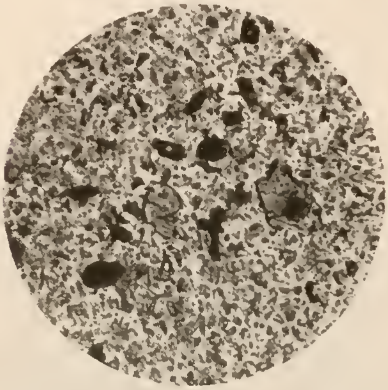
The ordinary methods employed for the separation of solids from the liquids in which they are suspended are:—1. Subsidence and decantation. 2. Ordinary filtration. 3. The use of centrifugals. 4. The use of the filter press. Whatever method is employed, efforts are always being made in the direction of producing a precipitate which is as dense and as crystalline as possible. Unfortunately some precipitates cannot be converted by any ordinary treatment into a form which render them amenable to easy treatment by any of the methods referred to above. Precipitates such as hydrated oxide of iron and similar substances of a slimy character are often very difficultly amenable to any treatment. The precipitates may be formed in hot solutions, they may be allowed to stand, or boiled; but in many cases such treatment does not lead to a suspension which can be readily handled.

The method of separation by subsidence works more efficiently the higher the specific gravity of the product and the larger the particle. The methods of separation by subsidence and by the use of centrifugal action are very similar, the difference being that the comparatively weak action of gravitation in the subsidence method is displaced by the much more powerful action of centrifugal force where the centrifuge is employed. Ordinary filtration and the use of the filter press resemble one another in general practice, but in the filter press mechanical pressure is employed to aid gravitation in pushing the suspending liquor through the precipitate and through the filtering medium. If the substance to be filtered is exceedingly finely divided and of a slimy nature the pores of the filter medium rapidly become filled and the filtering medium becomes impermeable.

Many works' wrinkles are employed, such as mixing in an inert substance such as fine clay, kieselguhr, and the like, from which the precipitate is afterwards separated by chemical action. Such assistance, however, cannot always be employed, and is not always efficacious.

We are left with a wide range of products classified under the generic name of colloids which are very difficult to handle. The group of substances known as colloids is so large that it is necessary to define more closely the range with which we wish to deal. Colloids range from the ultra-microscopic particles like some of the organic dyes, which are merely organic bodies of very high molecular weight, up to microscopic particles which would settle out of the suspending liquor in process of time. It has been found that almost any product can be made to behave like a colloid if it be sufficiently finely ground; thus silica, carborundum, emery, steatite, and asbestos can be reduced to so finely divided a form that they behave like clay or other true colloids and may be classified as pseudo-colloids. If a suspension of china clay be allowed to settle a layer will be formed at the bottom of the vessel from which the clear suspending water can be decanted, but such a deposit will contain 50—60% of water, and it will in general be found that the finer the particle the larger the amount of water contained in the layer which is eventually formed by subsidence. Ordinary peat such as is found in the moving bogs of Ireland contains 92—94% of water.

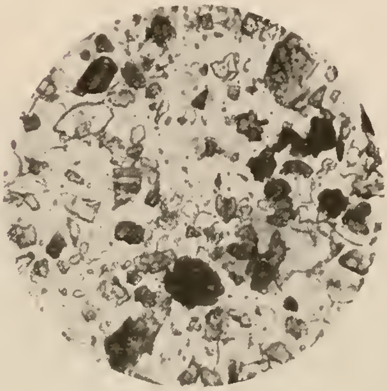
Sample of an ordinary commercial China Clay.



Cornish China Clay, untreated (x100).

FIG. 1.

Residue from (1) after short (1 hour) settlement, after addition of electrolyte.

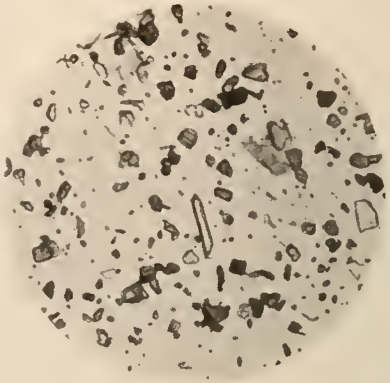


Cornish China Clay, deposit (x100).

FIG. 2.

The special method of treatment with which we have to deal now depends on the utilisation of certain properties of finely divided particles in suspension. This new process for the application of physico-chemical laws is in many respects so new that it is necessary to deal shortly with the underlying principles before the methods of their application, and the limitations of the process can be properly understood.

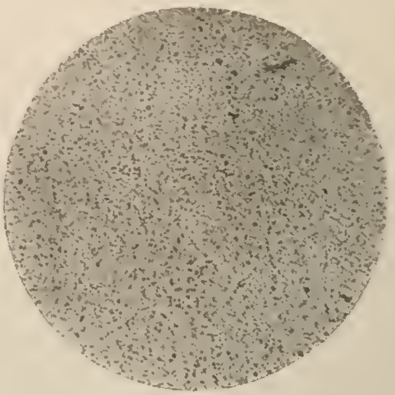
Residue rejected by the Osmose Machine from the slip taken off residue in Fig. 2.



Cornish China Clay, effluent deposit (x300), transmitted light.

FIG. 3.

Commercial sample of Osmose purified China Clay.



Cornish China Clay, Osmosed product (x100).

FIG. 4.

Colloids can be divided into two groups, the reversible and the irreversible. To the reversible group belong such substances as glue, gelatin, which can be dissolved in water, dried, and again dissolved in water without any great alteration in properties. To the irreversible group belong such substances as albumin, which after treatment with boiling water become absolutely insoluble. For the most part, however, the nature of the colloid is largely dependent upon the size of the particles. Sufficiently fine particles when suspended in water exhibit what is known as the Brownian movement, which is more energetic the smaller the particle. This Brownian movement is now regarded as the visible symbol of molecular bombardment, as has been largely proved by the beautiful researches of Professor Perrin. Generally speaking particles of matter exceeding 0·0001 mm. in diameter will eventually settle from solution. It happens that this is about the limit of microscopic visibility. The fact that particles below this limiting size do not settle means that the molecular and electrical forces outweigh the action of gravitation. So far back as 1869 Jevons noticed that the intensity of the Brownian movement of clay particles was increased by the addition of traces of certain types of substances and inhibited by the addition of other types of substances. In 1895 Bliss noticed that a clay suspension exhibited increased Brownian movement with the addition of traces of alkali, but that the addition of further quantities again reduced the movement.

It has long been known that the addition of certain types of chemicals tended to cause coagulation of colloids suspended in water; thus the addition of calcium hydrate and aluminium sulphate to bring about the settlement of sewage sludge is ancient history. Weber many years ago showed that the addition of considerable quantities of sodium carbonate and sodium silicate to mixtures employed in the making of pottery ware caused such mixtures to be thinner. This principle was utilised by him to enable " slips " to be prepared containing much more clay substance, flint, Cornish stone, ball clay, and other ingredients employed in pottery making to the gallon, and such " slips " are employed in the casting of pottery-ware in plaster moulds.

These are all illustrations to show to some extent the position of knowledge relating to the effect of electrolytes on colloidal suspensions. It remained for Count Schwerin to see the bearing of these little-studied laws in their commercial application. A very brief history of his work will be useful in showing you how a few accidental observations scientifically followed up have led to developments of the greatest technical importance. Count Schwerin at the University was working on the problem of removing the musty products of decomposition from albuminous materials, and in the course of some electrical experiments noticed that his colloidal products collected on the poles which he was employing in his experiments.

Being greatly interested in the problem of drying peat he tried similar experiments on a peat suspension, and found that the peat actually did travel to the anode and was deposited thereon. His efforts at that time were directed rather to the utilisation of electro-endosmose to the de-watering of peat, and to justify this end the peat magma was pressed between perforated plates which were respectively anode and cathode. On cutting through the dried peat mass so obtained he noticed that, although the peat suspension originally employed had been thoroughly mixed, nevertheless the section of the dried peat showed layers parallel to the anode, and he gathered from this experiment that under the influence of the current the various bodies in the suspension travelled with different velocities. Finding that one of the layers consisted largely of clay substance, the experiments were tried with a clay suspension, and it was found possible to deposit clay out of a water suspension on the anode. Starting from this basis the " Osmose machine " was gradually developed (this machine will be described later), but it was found that while one clay would deposit, another apparently similar clay did not react. Much experimental work led to the discovery that certain clays shaken with water have particles which apparently carry no charge. The next development was to make use of the fact that most colloids can and do adsorb considerable quantities of electrolytes to which they may be exposed, and it was found that by the addition of very small traces of suitable electrolytes such as caustic soda, and the like, the previously inert clays were rendered amenable to electrical action. Even now the difficulties were not overcome, for it was found that a few clays were still impossible of treatment. In many cases this proved to be due to the presence of traces of divalent salts which were soluble in water, and, as has already been pointed out, these divalent and trivalent compounds have an extreme power of neutralising the so-called peptising action of the univalent alkalis, bringing about the coagulation of the clay subsidence. Such cases can only be met by previous chemical treatment directed to the conversion of the coagulating electrolytes into insoluble salts.

The patents of Schwerin were directed towards the utilisation of the discoveries here referred to. The work thus originated, however, extended into many other directions. The principle of the selected movement of one type of colloid particle as compared with another, first accidentally discovered in the peat work, has been extended in many directions.

It is obvious that the properties of a colloid suspension can be greatly influenced by the nature of the electrolytes added to the suspension. It is known that various substances take on charges of different potentials when suspended in water, and it has proved possible to make filtering diaphragms having such a pore size and such a potential that it is possible selectively to remove from a number of organic colloids one or more from the mass. This is in a sense a sort of ultra-filtration, because in many cases the substances thus separated from one another are of a gelatinous nature, and entirely incapable of examination or separation under the highest powers of the microscope.

It is by the utilisation of selective adsorption and by choosing diaphragms of suitable polarity that it has been possible to separate from blood serum the fibrinogen, the euglobulin, and other substances, leaving a pure paraglobulin behind. The practical application of this discovery becomes obvious when we learn that in the preparation of anti-diphtheritic serum from horse serum it is possible to separate an anti-diphtheritic product having ten times the strength of that usually prepared directly from the serum. This achievement is based not only on the application of the principles above referred to, but on the discovery that the anti-toxin in blood serum is practically entirely combined with the paraglobulin, and that by isolating the paraglobulin from the anti-diphtheritic horse serum the concentration for medical purposes is increased manyfold. Obviously the removal of large groups of little-known and complex nitrogenous substances from the serum leaves a product which is not only medically more active, but carries with it a greatly diminished quantity of not only inert, but possibly harmful products. So much then for the general laws upon which the Osmose process is based.

In what follows reference will be made to the behaviour of a clay suspension, because clay is in many respects a typical colloid suspensoid, and the methods of dealing with clay have been further developed than any others. It is found that if one part of plastic clay be mixed with one part of water, a creamy mass is produced. In the case of a very plastic clay, *i.e.*, generally one having very finely divided particles, the mixture will be almost as thick as butter, whereas with a meagre clay not very plastic, such as ordinary china clay, the mixture may be only a thin cream. If to these mixtures we add a small amount of alkaline electrolyte, say 0·03% on the weight of the clay, a wonderful alteration is brought about in the physical properties of the mixture. In both cases the buttery or creamy mass will become very thin and fluid. The suspended colloid has been converted from the gel condition into the sol condition, and now all the particles are electrically charged, and to a very large extent have become dispersed and are in a much more finely divided state than was previously the case. Such a dispersed suspension is exceedingly difficult to filter by ordinary means, but use can be made of the fact that the clay particles are charged and can be deposited on an electrode of suitable polarity.

In order to show the enormous difference brought about in the physical state of a finely divided insoluble body suspended in water I will show the following experiment:—

Into two large cylinders, one containing water slightly acidified, and the other containing water slightly alkaline, I will pour a few drops of a clay suspension which had been washed with water, which is, in fact, a natural ball clay from Devonshire. You will notice that in the acid water the clay goes straight to the bottom, whereas in the alkaline water the clay is dispersed into an exceedingly fine cloud. This simple experiment is sufficient to show that the physical behaviour of a colloid suspensoid is greatly influenced by the nature and amount of the electrolyte in the liquid in which it is suspended.

We will now take a suspension of ball china, to which has been added the necessary amount of electrolyte, and will pour it into a copper cylinder having a carbon pole suspended in the centre. On passing a current of about 60 volts through the liquid so that the central carbon pole is the anode, you will see that the clay is not only deposited very rapidly on the anode, but, although the clay is deposited under water, nevertheless the clay on the anode will be found to be remarkably dry. This result is due to the peculiar action by which water is repelled from the anode through a porous diaphragm, the action being known as electro-endosmosis. It must be clear that if instead of using a stationary anode we use a horizontal rotating anode this process can be made continuous, and the small machine here shown is a working model of such a continuous plant.

The anode of the machine used is a rotaing drum made of an alloy to resist the corrosive action, whereas the cathode consists of copper strips placed round the anode, and distanced about ¾ in. therefrom. The bottom of the containing vessel contains paddles to keep the clay in suspension. The clay suspension consists of clay particles having a comparatively strong negative charge and other substances having a very feeble negative or no charge at all.

In the electric field between the cathode and the anode the clay particles are strongly attracted to the anode. The moment a film of clay has been formed on the anode the water contained therein is violently ejected towards the cathode, and this stream of water tends to sweep away all but the particles having a high negative charge, which, in spite of the water current, are drawn to the anode. The lantern slides show a sample of raw clay, then the impurities which settle out of the clay after the addition of the electrolytes, then the impurities which are rejected by the Osmose machine, and finally the clay as taken up on the anode.

It will be seen that the machine acts not only as a means for collecting clay from the water suspension, but is a selective collector, and simultaneously acts to a considerable extent as a drying machine.

From what has gone before it will, however, be obvious that the apparatus is not one which can be adapted without a thorough knowledge not only of the product to which it is to be applied, but also of the nature of the electrolytes present in the water in which the solid is suspended.

Although such a process cannot be considered as an ordinary filtration process, nevertheless it is, *inter alia*, a process for the continuous separation of suspended matter from suspending liquid with simultaneous partial drying of the solid product. Obviously such a continuous process can only be employed where large quantities of material have to be handled, but the same principle can be embodied in the Osmose filter press, which consists of an ordinary type of press made of insulating material, the filter cloths being placed upon insulated pieces of conducting material, such as wire gauze or the like. Into such a chamber the clay suspension can be passed under just sufficient pressure to ensure that the chamber keeps filled. Without the application of electricity under these conditions there will be no filtration, for the filter cloths would be choked from the first moment. By the application of a potential of 60 volts, however, the water is forced out through the cathode, and a firm, hard cake results very rapidly, and even in the case of plastic ball clay a 3-in. block can be made in an hour containing less than 30% of water. It will be impossible to produce a 3-in. block of ball clay in an ordinary filter press with 200 lb. per sq. in. in days, let alone hours.

The essential difference between the Osmose machine and the Osmose filter press lies not only in the continuous action of the Osmose machine, but in the fact that the machine brings about a certain selective purification or separation, whereas the filter press by its nature merely serves to collect the whole of the suspended product.

It is obvious that this method of dealing with colloidal substances is only applicable in special cases, and that every case requires study to find out the conditions under which the body is amenable to treatment, if at all. The application of these little known properties of suspensoids and colloids would appear to have a great future, but much research is required.

The Osmose Co., Ltd., have carried out a great deal of research work on the application of the Osmose principles to the treatment of clay, but have concentrated in the first place on the continuous Osmose machine. Their work on the Osmose filter press is far advanced, and they hope shortly to be able to deal with this side of the subject on a commercial scale. Their work on the selective filtration by means of diaphragms is also well advanced, and in the near future should be the subject of large and valuable commercial application.

The company are always glad to hear of any problem to which their process seems likely to be applicable, and are at all times willing to carry out experimental work where the nature of the problem seems to justify this.

DISCUSSION.

Mr. C. S. **Garland** remarked that in listening to Dr. Ormandy one had the feeling that he had strayed into the wrong lecture theatre. Whilst they had all been interested in the paper, the chemical engineering part of it was not its strongest point. He would like to ask the author if the filter press was a practical machine, and if so where it was obtainable, and whether Dr. Ormandy could give them any idea as to its output. He was intensely interested in the thing if it was practicable.

Mr. W. **Ramsay Sibbald** asked whether this process was applicable to suspensions in liquids, other than in water. There were innumerable patents covering the separation of oil in suspension in water by electrolysis, and he was wondering whether this could be applied to the separation of fine suspensions in vegetable or mineral oils.

Mr. **George King** said he was very much interested in the use of the diaphragm especially. As chemists they were usually interested in the separation of precipitates from solutions containing a considerable proportion of electrolytes. He would like to know what excess of alkalines was necessary in order to make a separation. Also just to what extent it was possible to wash out electrolytes, and the proportion of moisture left in the dried material. Further, was the drying material dried simply because of the heat on the cylinder, or was it dried by electro-endosmosis.

Mr. A. E. **Malpas** said he did not know whether Dr. Ormandy had made a little slip in his opening remarks or not, or whether he quoted facts. He gathered that the author said that in a solution between platinum electros, on applying a current they got a deposit on both poles. He confessed he did not know much about this Osmosis method of precipitation, but to-day, of course, we were using on a large scale and extending the application of what was known as the Lodge or Cotterill for the precipitation of dust from gases. In the Cotterill process they used electricity at a higher voltage. They used a uni-directional current up to 80,000 to 100,000 volts, and therefore they got a precipitate on the cathode and there was no precipitate on the anode. It was to be regretted that in this paper they had no diagram showing the construction of that little machine, and he thought if Dr. Ormandy could show it in operation it would be a kindness on his part. The type of machine they knew in a different form was the rotary vacuum filter. It was evidently designed on these lines, but they had used the Osmosis principles to make it work for colloids. The moment they got the precipitate in the finely-divided state it blocked up and did not work at all well. The author had got over that difficulty because he was treating the colloids in a perfectly practical way. Mr. Malpas was glad to see he had achieved such a good result.

Mr. E. C. **Williams** said he would be glad to know if Dr. Ormandy thought this could be applied to highly complex organic bodies. In the organic chemical industry they had serious problems arising from bodies in complex oxidation. Products were formed, especially when lime or free gas was present. Could this method be applied to the filtration of these highly oxidised organic bodies.

Mr. A. T. **Henley** asked if this process had already been applied, or if it could be applied to the continuous sterilisation of liquids in bulk by removing the bacteria.

Mr. H. H. **Morgan** inquired if Dr. Ormandy had had any experience of this method in the preparation of calcium carbonate, and also in the clarification of suspensions in non-aqueous liquids of very poor constitution.

Dr. **Thorne** said he was sure many present would have liked to have seen the action of the little apparatus with the revolving drum.

Mr. L. P. **Wilson** asked Dr. Ormandy whether he had had any experience of, or any information in the use of this process in connection with the purification of such substances as dyestuffs which very frequently contained a small proportion of some matter which was generally considered impossible of removal, and which in some cases was rather troublesome. Also he would like to know whether it was possible to separate from a solution—he did not mean suspension exactly—but a boiled starch solution. Could the starch be removed from such a liquid as that.

Dr. **Ormandy**, replying to the discussion, said a large number of points had been raised. Taking Dr. Thorne's first, the reason that he could not show the machine at work was that it required two small motors to drive the stirring gear and the very slow motions of the large wheel, and also it would require that he should have brought a very considerable amount of clay slip. But he thought they would see how quickly the clay gathered on the anode. With regard to Mr. Garland's question about the filter press, it was being used in Germany, but they had not got the information through yet. They had devoted attention to the Osmose machine as a commercial success. In Germany the filter press had been developed to an instrument of two metres in diameter, capable of handling half a ton of colloidals. We in this country were not so far as they were. There were considerable difficulties in constructing this machine, as the electric pressures used were very considerable. The cost of treatment for current in either the filter press or the Osmosis machine varied with the nature of the clay and the nature of the water impurities in the clay, and they might get as low as 2 units or as high as 10 units of clay turned out from the Osmosis machine or the filter press. From that they could gather what the cost would be. Mr. Sibbald had spoken about the utilisation of other liquids, and the separation of water from oils, and vegetable matter in oils. That was a side they had not had an opportunity of working on here, but he had been told that the Berlin branch had dealt with the matter and had succeeded in getting from glycerides the salts and the colouring matters, and were able to produce a glycerine which, after filtration, would evaporate down to dynamite glycerine. As to how much excess of alkali was necessary, the total amount of electrolyte added was ·03 % on the weight of the clay. The conductivity was very low. The greatest loss of current was generally due to the presence of electrolytes dissolved out of the water from the clay substance itself. The drying of the clay could not be due to heat because to produce a clay slip from this consistency down to 30 % clay slip would require an expenditure of electricity. Mr. Malpas seemed to think he had made a mistake when he said that on the platinum wires, negative and positive, there were deposits. The Cotterill was a purely electro-static process. Mr. Williams had spoken about dealing with complex organic bodies. It was quite possible to deal with residues from fusions containing a large amount of caustic soda. It was possible, he believed, to bring about selective separation of certain dyes if one happened to be electro negative and the other electro positive, but it was contingent upon the dyes being suspended in liquor which was not rich in conducting bodies. Mr. Henley had spoken of the sterilisation of organic liquids. One of the great applications of it in Germany, working in connection with the Rockefeller Institute in New York, was for the sterilisation of vaccines. It was possible to kill live bacteria in a vaccine. Mr. Morgan had spoken with reference to calcium carbonate. He could not say he had tried. He did not know what would happen. It was possible to use this phenomena in non-aqueous solutions, but it was a branch which was just being started. With regard to the separation of starch which had been dealt with, he could not say. It was possible to drive the various bodies out of glue, leaving chemically pure gelatine, and that was a problem of the same order. In conclusion Dr. Ormandy said it was intended to get £25,000 together in order to start the first Chair of Colloidal Chemistry at Manchester University. The Osmose Company of Germany had spent £27,000 in salaries to scientific men in the past 12 years, and we could not hope, in our small way, to arrive at the position they had arrived at after the money they had spent. It was, candidly, a disgrace that this country had nowhere a Chair of Colloidal Chemistry in the whole country.

THE SHARPLES "SUPER-CENTRIFUGE."

BY S. H. MENZIES.

If amongst the many and varied uses to which the prefix "super" has been applied there exists one instance in which it is warrantable, without a doubt the Sharples design of centrifuge may justly claim that characteristic.

Superlative in speed of rotation, and superlative in results achieved, it unquestionably is: and whilst all forms of construction and types of equipment have their limitations, the field of useful application for this machine is immense and widening daily to an extent which tempts one almost to characterise it as unlimited.

The Sharples "super-centrifuge" applies the settling action of gravity highly intensified in two classes of operation, *viz.*, that in which solids are settled out of liquids, which may be terms "clarification," and that in which one liquid heavier or of higher specific gravity is settled apart from another liquid of lower specific gravity. For the purpose of the paper this latter operation will be termed "separation."

Many centrifuges perform to a greater or smaller extent the operation of filtration, in that suspended matter is held back upon a surface through which the enveloping liquid passes. Such is not the case with the Sharples "super-centrifuge," since the action which takes place in the case of "clarification" of a liquid from suspended solids is a "subsidence" pure and simple and not in any sense a "filtration."

"Clarification" covers innumerable operations varying widely in character and rate of settlement according to the size and specific gravity of the solid particles, and also the viscosity of the liquid of suspension.

Similarly, in the separation of liquids from one another, the ease with which the liquids can be parted will differ according to the actual difference in the specific gravity as well as other circumstances. Not only are both of these actions intensified and facilitated when taking place in the "super-centrifuge," but by means of the enormous force generated in the Sharples machine very many "clarifications" and "separations" have become commercially possible which previously were either impossible or only effected at extravagant expenditure of time or money or both.

Obviously the greater the extent to which this settling action can be intensified the greater will be the increase both in the number of processes available in the field of the industry and in the economic and technical advantage of each individually.

Two factors in a centrifuge contribute to such intensification, *viz.*, the diameter of the rotating member and the speed with which it revolves. And it is principally the question of safe mechanical stress which fixes in each case the limit to which increase may be taken.

A point illustrative of the value of revolutions as against diameter worth recording, however, is that despite the immense diameter of the earth, and a peripheral speed more than four times that of the small super-centrifuge exhibited here (which rotates at 40,000 r.p.m.), the centrifugal force generated without regard for the action of gravity is only an infinitesimal part of the force generated in the "super-centrifuge."

The essential fact is that centrifugal force varies directly with increase of diameter, but as the square of the number of revolutions per minute.

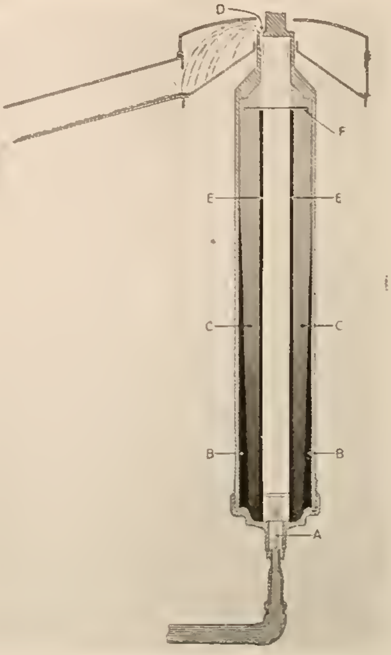
It is easy to see, then, that of these two, in seeking to intensify the centrifugal force in order to keep within the limit of safe mechanical stress, diameter must give way to revolutions per minute. Hence arises the tubular pattern of centrifuge evolved and perfected by the Sharples Company through two generations of study and invention.

A few points of interest in the general construction of the machine may be briefly touched upon, and will be seen in the screened pictures and appreciated upon examination of the machine exhibited.

Since centrifugal force varies directly with increase of diameter, and as the square of the speed of revolution, the centrifuge in question has been constructed of tubular pattern.

The rotating member, or "bowl," is both supported and driven from the top, being otherwise entirely free to find its own axis. By these means the machine is operated with the minimum of wear and tear. One main ball-bearing constitutes the sole point in the machine at which friction has to be taken into account. The drive, arranged immediately above this main bearing, takes four alternative forms, viz.:—

(1) A pure belt drive from line shaft.



The Process of Centrifugal Clarification.

(2) Direct steam drive by means of a turbine wheel fixed to the tube or bowl spindle.

(3) Indirect electric drive, *i.e.*, individual motor mounted on the centrifuge body and driven by short belt and idler pulley on to the head of the bowl spindle.

(4) Direct electric drive in which the motor armature is mounted on and an integral part of the bowl spindle. Mechanical friction losses are thus limited solely to those of the one ball-bearing which carries the rotating bowl. A considerable reduction in consumption of power is effected in this instance.

At the bottom of the bowl a short extension runs with a definite permitted clearance in a bushed socket, serving as a guide during the running up to speed of the bowl, when slight vibration or oscillation may occur. The liquid to be treated is admitted through the hollow centre of this extension of the bowl either under greater or less head, or in certain cases positive pressure, according as viscosity or other considerations demand. Settlement takes place during the upward travel of the liquid, which discharges at the top of the machine through one or two outlets, according as the process in hand is that of "clarification" or "separation." In the former case the suspended solids normally are deposited on the inside wall of the tube or bowl, and these solids are intermittently removed from the bowl as and when it becomes fully charged.

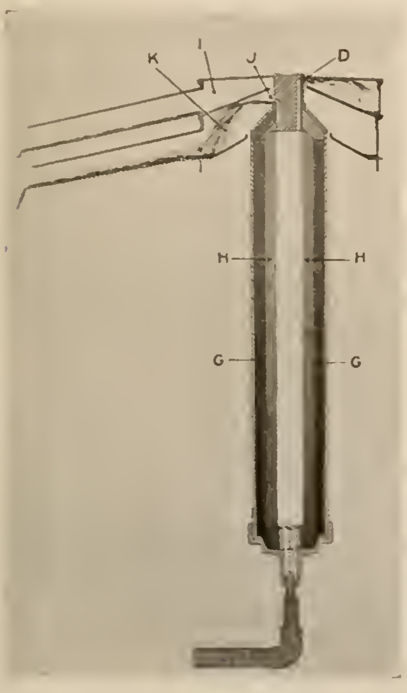
With the exception to be mentioned, this intermittent removal of settled solid matter governs mainly the economic consideration of the "super-centrifuge," since the labour charges incident thereto directly affect the profit of the process, other considerations, such as the value of perfect clarity of the liquid or of the solid removed, being taken into account.

Attention to the design of the bowl and surrounding parts has reduced to a low point the time and trouble and consequent expense incident to bowl changing, and cleaning of one bowl is carried out at leisure whilst another is loading up.

One coupling only has to be slackened off in the main spindle above the bowl, when the latter is immediately withdrawable, and the entire cycle of stopping the machine, changing bowls, and running the machine up to speed again is easily effected by an unskilled operator in three minutes.

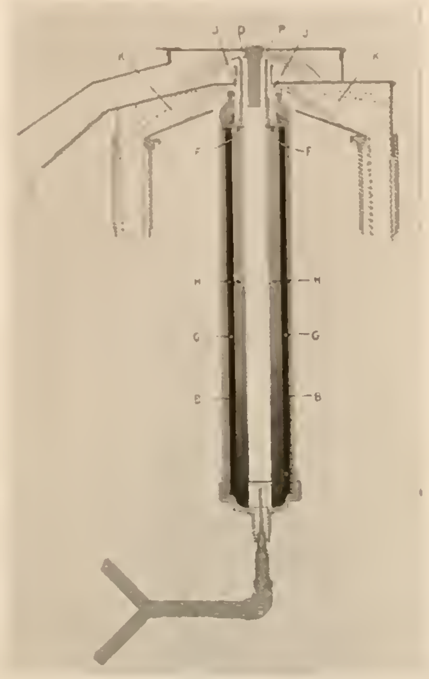
In certain industries a large diameter and slow-running centrifuge may be an economic primary stage to the final intensive treatment in the "super-centrifuge." By this means complete clarity would be secured in liquors heavily charged with solids which could not otherwise be economically handled in the "super-centrifuge." As an alternative to this liquors high in suspended solid content are given a preliminary gravity sedimentation before centrifuging.

Two typical processes in connexion with "clarification" which might be cited are those of dry cleaners' benzine recovery and the clarifying of lacquer or nitrated cellulose. In the former we have an instance of a heavy suspended material in an extremely light liquid, whilst in the latter very light solid material is suspended in a heavy and highly viscous liquid.



The Process of Centrifugal Separation.

In both cases in the "super-centrifuge" clarification is complete and the suspended solids entirely eliminated. These two cases, however, afford good examples of the manner in which physical characteristics affect capacity of the machine. In the case of benzine clarification the flow through a Sharples "super-centrifuge" can be taken comfortably to 250 galls. per hr., whilst in the case of the nitrated cellulose, where the process is one of eliminating fine vegetable fibres of cotton or pieces of cotton-husk, the flow through a Sharples machine to secure the best grade of lacquer entirely free of all solid suspension usually does not exceed 70 to 80 galls. per hr.



The process of centrifugal clarification with continuous discharge of solids.

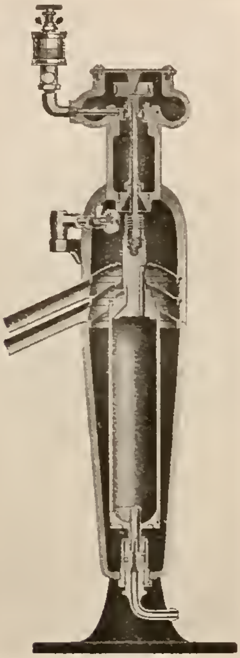
In one factory the introduction of a Sharples "super-centrifuge" completely revolutionised the process of manufacturing this nitrated cellulose. Prior to its installation the firm in question found it essential, in order to maintain the high character of their output, to purchase only the most expensive grade of cotton wool, whilst after the introduction of the clarifying process by means of the "super-centrifuge" it was unnecessary to pay any particular regard to the grade of cotton which was employed, since any impurities remaining after nitration were easily and completely removed, and the final product still maintained at its high excellence. A reduction in the contributory cost of this raw material by over 50% was thus effected.

In the "super-centrifuge" treatment of varnish one of two objects may be accomplished. Where ageing is not carried out to any great extent the complete removal of all suspension which would mar the coat or settle in the can is effected, and a brilliant product results. In the case of varnish which has to be aged, treatment by the intensive "super-centrifugal" force will secure a firm, thin layer of sediment not easily disturbed on decantation, as against the bulky sludge, which proves troublesome by reason of its ready disturbance during decantation.

Where "separation," as defined earlier in the paper, is alone in question two characteristics are essential in the constituent liquors, viz., immiscibility and difference of specific gravity.

No centrifugal treatment has as yet been developed which will effect separation of one liquid from another in which it is capable of forming a true solution. Nor can separation be effected without artificial aid other than pure centrifuging of one liquid from another of the same specific gravity. Emulsification, no matter how complete, of immiscible liquids which are of different specific gravity does not constitute an insuperable obstacle in the case of the super-centrifuge.

The question of prime importance to securing quantitatively economic, as well as qualitatively satisfactory results, is the correct design and relative position of the two outlets. For example, both form and position of discharge outlets would in the case of the dehydration of water-gas tar vary widely from those requisite for the recovery of vegetable oil from soap stock. An immense amount of research and study has been devoted to this subject at the Sharples works, with a resultant success which has created wide expansion of the range of processes brought under satisfactory " super-centrifugal " treatment.


The Sharples super-centrifuge, laboratory type, turbine driven.

Specific gravity, viscosity and the globule character (in the case of fine emulsions), besides other factors, all enter into the consideration of the type and design of bowl. And these have in the main been reduced to well-defined and classified types, covering ranges of purpose.

In a number of cases contributory processes to the central function of the " super-centrifuge " have been worked out by careful test and research, a prominent example being the separation and continuous discharge of amorphous wax from cylinder stock. This result, previously impossible in a centrifuge, has been achieved by carrying out the entire process at a very low temperature and employing a carrier liquid immiscible with the oil and of greater specific gravity than the heavy wax, upon which the wax is floated off in a continuous discharge. The diagram of action in the super-centrifuge shows very clearly what happens in the bowl.

In short, there lies open to the " super-centrifuge " properly designed to meet the limiting conditions of different problems a very wide and far-reaching field of processes in which not only technical satisfaction—or what might be termed qualitative settlement—may be secured; but by careful regard to surrounding contributory factors sound economic or quantitative (and therefore profitable) results may be secured.

The laboratory machine (see fig.) is a still further development of the sacrifice of diameter to revolutions, and emphasises the resultant gain mentioned at the outset, since in the commercial or full-sized Sharples super-centrifuge a separating force is developed at 17,000 r.p.m. of 16,950 times that of gravity, whilst in the laboratory machine a force over 40,000 times that of gravity is developed, and a means for effecting hitherto impossible separations, as also for facilitating qualitative and quantitative physical analyses, is afforded.

The opportunities presented by the machine include such processes as the separation of finely-divided wax from an alcoholic solution of shellac; the separation of bacteria from serums, for which the machine found a wide use during the recent war; separation of pigment from paint and enamel, and quantitative analysis of these.

Many complete processes have been worked out in which the super-centrifuge itself constitutes but one feature; amongst these may be mentioned the recovery of neutral wool fat from scouring effluent; the separation of vegetable oils from soap stock; the dehydration of water-gas tar; clarification of glue and of nitrocellulose liquors, and the separation of wax from mineral oil as before mentioned.

As an illustration of the action of the super-centrifugal force upon serum, a sample submitted for treatment from which all the corpuscles had been previously filtered off, and which appeared absolutely free of suspended matter clogged a Berkefeld filter after passing 200 c.c. Treatment through the super-centrifuge eliminated the bacteria thus evidenced to the extent that 20 litres did not clog the same Berkefeld filter.

As already stated, the rate of subsidence of solids suspended in a liquid when under super-centrifugal force will vary with their size and the viscosity of the liquid in which they are suspended. A series of experiments carried out in the Sharples Research Laboratories produced some figures from which it was shown that particles of 1 μ-radius suspended in water and varying in density from the surrounding water by one-tenth were moved through 1 cm. at varying centrifugal intensities in the following times:—

Under force	100	times gravity	..	.	1⅓ hrs.
" "	1000	" "	..	..	8⅓ min.
" "	10,000	" "	..	..	50 sec.
" "	40,000	" "	..	..	12 sec.

In the recovery of vegetable oil from soap stock the Sharples process and " super-centrifuge " has proven itself within the last couple of years to be a vitally important factor. The soap stock left in the refining kettle after neutralisation of the free fatty acid by caustic soda (which has as a rule been sold as such to the soap makers) contains on an average 25% of entrained oil capable of recovery. The value of any of this oil which can be separated from the soap stock may be taken as being from two to three times as great as the equivalent fatty acid content of the soap stock. Such oil therefore is enhanced in value by the same amount. Of the total free oil content in the soap stock 60—80% may be taken as recoverable by centrifuging; the balance of the material, consisting of a small percentage of free oil with the bulk of the residual soap stock when discharged from the machine, is usually pumped to lead-lined tanks where sulphuric acid is added, and the black grease or acidulated soap stock recovered. The following figures, relating to the economic aspect of the employment of Sharples "super-centrifuge" machines are the result of actual experience in several refineries in the United States:—

Total fatty acid in the soap stock 44%; oil recovered 12 lb.

12 lb. oil at 17c.	$2·04	
32 lb. black grease at 6c.	1·92	
Total value of recovered products ..	$3·96	
Less original value of 100 lb. of 44% soap stock at $2·64	2·64	
Gross profit from treating 100 lb. soap stock	$1·32	
Less cost of treating	·13	
Net profit from treatment of 100 lb. soap stock	$1·19	
Daily profit from treatment of 200,000 lb. at $1·19		$2380·00

All-round cost of installing battery equipment of Sharples "super-centrifuge" machines to handle this output, including accessory equipment, the total operating cost (allowing conservative figures for labour and power, 10% depreciation and 7% interest on capital outlay), works out at $253 per day, or, say, 13 c. per 100 lb. soap stock. From these figures it will be apparent that the actual capital outlay to instal Sharples "super-centrifugal" treatment in an oil refinery for recovery of oil from soap stock is returned at least once in every three months.

A review of the value of oil products for several years will show that the gross profit of the process can be conservatively computed as being the market value of one half of the recovered oil, the value of the other half of the recovered oil and the recovered fatty acid together equalising the original value of the soap stock.

A photograph of one of the installations of Sharples centrifugal machines operating in an oil refinery, which contributed to the figures thus given, will be seen.

An interesting case of the application of the Sharples "super-centrifuge" machine to a waste product which was previously a drug in the industry may be mentioned in the case of the so-called "bottom settlings," or "B.S." as it is commonly known in the American mineral oil industry. In the United States a large part of the B.S. emulsion which was available was a total loss. In times past much of it has been drained out from the discharge tanks to open ponds and allowed to stand indefinitely, and in some cases good oil has been poured over the top of these ponds and the whole pond set on fire to get rid of it. This emulsion contains on the average from 20—30% of good oil, sometimes as much as 50%. After this oil has been recovered it has always brought full market value, primarily because the crude oils which form emulsions most easily are the paraffin base oils where the paraffin is of high value. We estimate the profit from this process many cases the profit is really more than this, because the emulsion is more of a liability than an asset, as by most of the previous methods in use a larger amount of tank storage is required, and the cost of removing the emulsion by steaming is equal to the value of the recovered oil.

It is hoped that the foregoing will give some idea of the principal mechanical features of the Sharples "super-centrifuge," as well as of the wide field of processes into which it has successfully entered, and which is daily expanding.

DISCUSSION.

MR. E. F. BREWIS asked at what speed the machines rotated, and whether it was easy to dismantle the rotor and clean it out in the case in which they had solids to remove from the liquid. He had had the opportunity of handling one of the small machines, and the removal of the rotor and cleaning it to take out the solids deposited in the rotor seemed to him to be rather difficult and took some time. Of course it could be done, but it took rather a long time to dismantle the rotor and clean it, and then put it in working position again.

Mr. R. S. Morrell said he had had occasion to see the small laboratory machine, and he found a slight difficulty in dealing with viscous liquids which were partly solid, or where the solidity increased, he found there was a rise in temperature, so that although the effluent was at first clear, it became clouded. Was that the fault of the apparatus? It might have been his fault, but the machine was not so efficient as he could have desired. Probably, if this was a true defect, they would hear how it could be overcome.

Mr. William McD. Mackay said that in dealing with wool fat the author had spoken of the heavy particles. Was the liquor simply allowed to stand?

Mr. Menzies, replying, said as regarded Mr. Brewis' question, the speed of the machine on the bench was 40,000 a minute. The speed of the larger commercial machines, the normal speed, was 16,000 to 18,000. Perhaps 16,000 was more usual. He thought the point Mr. Brewis raised as regarded the cleaning of the bowl was one he might have mentioned previously. It was very important to the whole process. Apart altogether from what he might term the technical efficiency of the machine, there came up the economic efficiency, and the economic efficiency hinged entirely on the question of bowl cleaning, so far as clarification was concerned. Therefore in all cases where at least one machine was in question, it would be desirable that there should be a spare bowl, so that the getting rid of the solids extracted need not hinder the continuance of the operation on further batches of liquor. As a matter of fact, that was done frequently, even in single machine installations, and in New York, where the conditions were quite as bad as they could possibly have them, he had seen one of those very rough dry-cleaning men stop his machine, uncouple, take the bowl out, substitute a new bowl, couple everything up, and have his benzine turned on and clarifying again by his (Mr. Menzies') watch inside three minutes, and the man did not know that he was being timed.

Mr. Brewis.—That was not with a laboratory machine.

Mr. Menzies.—No. A full size No. 6. They were treating 200 to 250 gallons an hour.

Mr. Brewis.—The laboratory machine is a little more difficult.

Mr. Menzies replied that possibly it was, but one might observe that the question of economic efficiency did not enter so much into the laboratory as into the factory. Mr. Morrell had raised the question as regards the clarification of viscous liquors. He would suggest that probably the only means for overcoming any difficulties which might arise from that would be to provide artificial means for either cooling or heating the liquor to a point at which the final liquor which was under treatment would settle so as to cause after-crystallisation. He had been asked about the presedimentation of wool grease effluent. In the case he had mentioned the sedimentation took place in a large concrete tank in 12 hours, with two batches in a day. That served the whole of the 40 machines.

THE "STURGEON" SELF-DISCHARGING CENTRIFUGES FOR SEPARATING SOLIDS FROM LIQUIDS.

BY R. A. STURGEON.

The Sturgeon centrifuges are continuous running, self-discharging machines, for separating, by centrifugal sedimentation, fine solids from liquids. Rotation may be continued, without intermission, throughout the day, during which time the liquid under treatment passes through the machine, leaving its suspended solids behind. These deposited solids are periodically ejected by a method which has never been adopted before in self-discharging centrifuges.

As this is the first paper dealing with the "Sturgeon" centrifuges, it is appropriate to give a short historical survey of their development, and the state of the art at the commencement of the author's investigations.

It was known that many abortive attempts had been made to produce a practical self-discharging centrifuge. The actual outcome of most of these efforts was obscure, but enough was known to make it clear that the production of such a machine was an extremely difficult problem.

There were two main lines of attack—one on that class of machine which may be best described as a centrifugal strainer, in which the liquor is strained off granular solids through a sieve, and the other type of machine depending on separating fine suspended solids from their accompanying liquor by centrifugal sedimentation. The solids in the latter case may be so finely divided that they will either pass through or clog any mesh that could be provided, and the drum must therefore have a solid wall.

The separation of a liquid from a granular solid is undoubtedly by far the easier problem, for in that case the separation has been completed before the discharge of the solids from the machine takes place. In fact, it is possible to arrange for a continuous discharge of the solids.

The latter problem, in which very minute particles of solid matter are concerned, is the one now mainly under consideration, and it is rendered more difficult by the fact that the solid and liquid will automatically separate into a deposit and a surface liquor. That surface liquor must be removed before the solid matter can be recovered. An attempt to deal with this problem on continuous lines was made by the Separator Company, of Sweden, by scraping up the deposit, drawing it through the liquor, and so discharging it. Obviously this resulted in a very wet discharge-product, and the attempt was abandoned. A full consideration of the subject made it clear that a machine for dealing with fine suspended solids *must be discharged intermittently.*

Two types of machine constructed for intermittent discharge of the separated solids were known to the author at this early stage. One, in operation in Frankfurt, Germany, consisted of four radial arms, into which the liquor under treatment passed and was filtered. After a time, valves, opened by oil pressure, released the filter deposit from the outer end of each arm. The output was necessarily small, and the gearing and accessories complicated and costly. The other machine, in operation at Ostend, had a stationary scoop which removed the surface liquor and then the solid deposit. The power required during discharge was very great, as it was necessary to scoop into a dense, closely packed mass of solids, which was travelling at a rate of, say, 100 to 200 ft. per sec. The wear of the scoop was excessive.

The magnitude of the forces to be overcome in effecting the discharge of a solid deposit in a centrifuge running at full speed is indicated in the following example:—In a centrifuge, 36 in. diam. and 15 in. deep, revolving at 1000 r.p.m., with a deposit of solids (sp. gr., say, 1·5) having a mean thickness of 2 in., the actual weight of solids would be 170 lb., and the centrifugal force would amount to about 36 tons. Hence it is required to remove a mass equivalent to 36 tons every time the machine is discharged whilst rotating at full speed.

After careful consideration, the following basis for design was laid down in developing the Sturgeon machines:—

(1) The surface liquor and the lightest portion of the solids must be removed before the main deposit is discharged.

(2) There must be no attempt to overcome, by direct means, the centrifugal force of the deposit. The only forces to be overcome must be frictional resistances, while all the main forces must be balanced in some way.

(3) The power for effecting the discharge must be obtained through the main drive to the centrifuge, and must not be dependent upon accessory machinery.

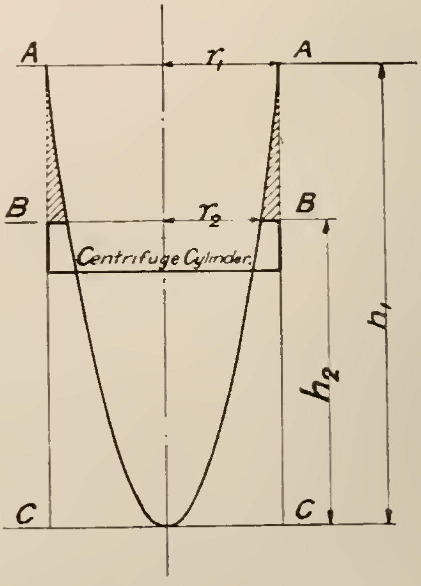
(4) The effective volume of the separating chamber must be the maximum obtainable for a given diameter of machine.

Pressure produced in Liquid by Centrifugal Force.

Several attempts were made to design a machine to meet these conditions, but the results were not very satisfactory until the use of the pressure produced in a liquid by centrifugal force was introduced to operate the discharging mechanism.

The value of this idea, which is the basis of the "Sturgeon" centrifuges, had, curiously enough, escaped the notice of previous investigators, although this pressure was ever present, and had to be allowed for in designing centrifuges.

An analysis of the pressures obtained in a liquid by centrifugal force is of interest. When a liquor is rotated at a high speed in a closed cylindrical vessel, it climbs up the sides, leaving a hollow core in the middle, and forming what is known as a forced vortex. The inner surface has a slope, the tangent of which is (centrifugal force)/(gravity). The curve is parabolic, the internal hollow being a paraboloid (see diagram).



The height of the paraboloid above the bottom of the curve is $h = \omega^2 r^2 / 2g$ where ω is angular velocity, and r the radius of the surface of the liquid at height h. The axial pressure on BB is that due to the weight of the column of water between AA and BB (shown shaded).

The weight of this column
$=$ W (volume of cylinder AACC − vol. of paraboloid on AA + vol. of paraboloid on BB − vol. of cylinder BBCC).

$$= W(r_1^2h_1 - \tfrac{1}{2}r_1^2h_1 + \tfrac{1}{2}r_2^2h_2 - r_1^2h_2)$$

Substituting for h_1 and h_2 and simplifying,
Weight of column $= \omega^2 W(r_1^2 - r_1^2)/4g$, where W, g, r_1 and r_2 are in corresponding units.

Reduced to a convenient form for general application,
Axial pressure $= 0{\cdot}0505(N/1000)^2(D_1^2 - D_2^2)^2$, where N = revs. per min., D_1 = outside diameter of column in inches, D_2 = inside diam. of column in inches.

The intensity of pressure is obtainable from the formula:—

p (in lb. per sq. in.) $= 0{\cdot}128(N/1000)^2(D_1^2 - D_2^2)$.

Hence the maximum axial pressure obtainable in the example just given, of a 36-in. machine at 1000 r.p.m. would be 37 tons, so that there is evidently a very substantial force available for the operation of a suitable discharging mechanism. The maximum radial pressure is 166 lb. per square inch.

The first machine with the discharge operated on this principle is described below:—

"Sturgeon" Centrifuge for De-watering Solids.

Fig. 1 is a section showing the valves, and Fig. 2 shows the centrifugal levers. The cylinder, *a*, has a fixed cover, *b*, at the bottom, and a movable cover, *c*, at the top.

The shaft, *d*, is carried by bearings at both ends, and is rapidly rotated by means of a belt-drive on pulley, *e*, or by other suitable means. The cover, *c*, is normally held down on the cylinder, making a joint by means of the levers, *f*. The centrifugal force of the lever weights acts through the linkage, *g*, to keep the cover on its seat. The levers allow of a limited lift of the cover, *c*. A piston, *h*, slides up and down the shaft. Attached to the top cover, *c*, are vertical valve rods, *k*. When the piston reaches its top position it lifts the top cover off its seat, thereby operating the valve rods which open the valves, *l*. When the piston descends to its bottom position it closes them. The shaft, cylinder, and all parts connected thereto revolve about the axis.

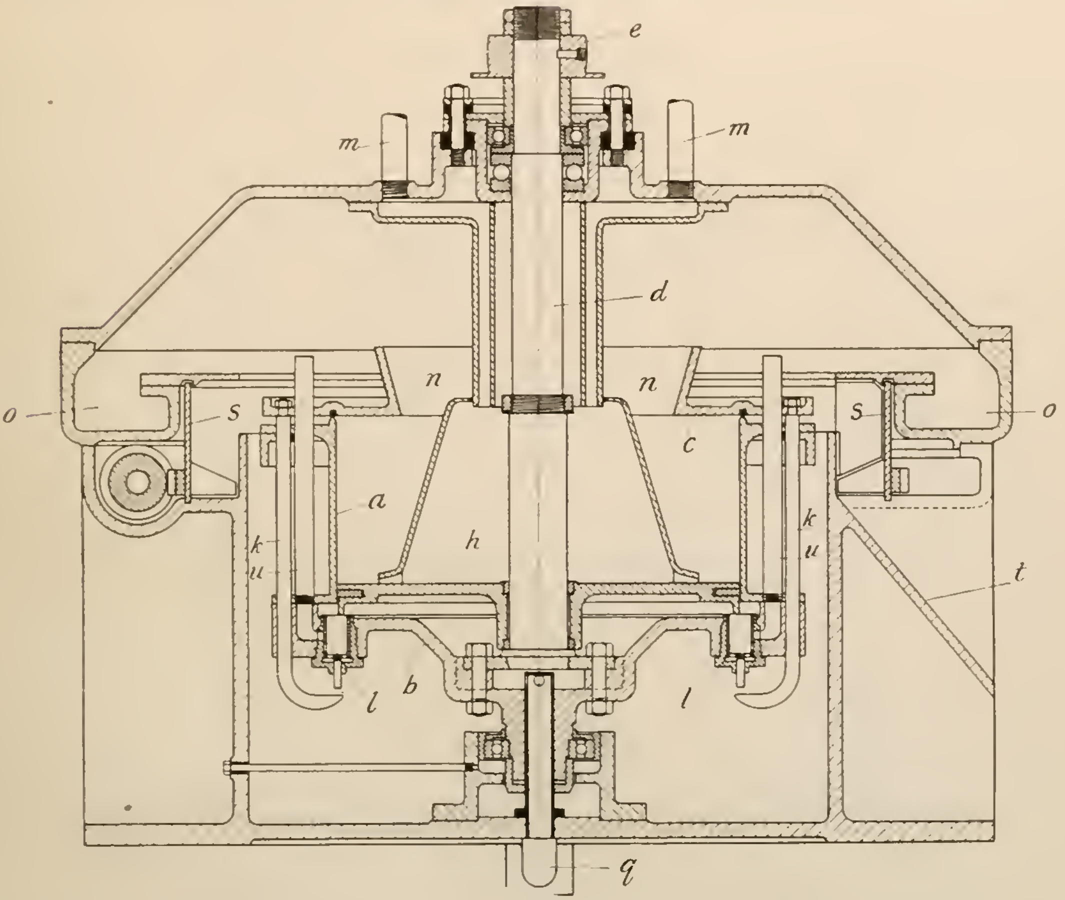


Fig. 1.

The machine is started, and the liquid to be treated enters the top frame through the pipes, *m*, passes into the cylinder, and is propelled to the periphery by centrifugal force. It fills up the cylinder and is discharged over the edge, *n*, into the circular trough, *o*, from which it passes away through the pipe, *p*. During the passage of the liquid through the machine the solids are deposited on the inner surface of the cylinder, and the clarified liquid passes away. When it is required to eject the deposited solids the supply of liquid is cut off, and water is admitted to the under-side of the piston through pipe, *q*. As the piston rises the wall of solids becomes thicker and more compressed, and the surface liquid is drained off over the edge, *n*, until the solid deposit only is left. Eventually the pressure on the top cover becomes so great that the pull of the levers, *f*, is overcome, the cover lifts, and the solids are discharged on to the circular revolving plate, *s*. As *s* revolves the solids are scraped off and fall down the chute, *t*, whence they are disposed of as required. The water supply is then cut off.

When the top cover is lifted to its top position by the piston it opens the valves, *l*, by means of the rods, *k*, and the water is discharged through the pipe, *u*, into the trough, *o*. As soon as the pressure on the piston falls sufficiently the levers, *f*, come into action and close the cover, *c*. When the water has all escaped the machine is ready for a fresh charge. The liquid is again admitted and forces the piston down to the bottom position, closing the valves in so doing. The cycle of operations is then completed.

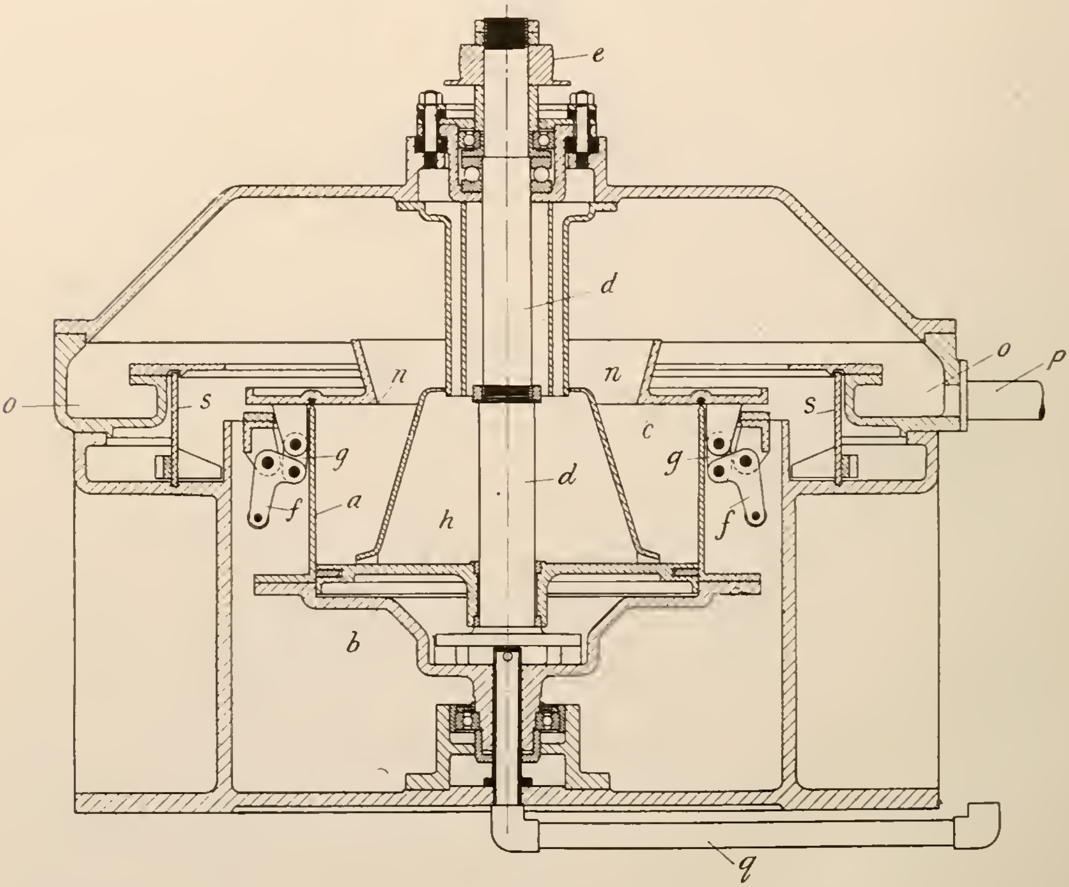


Fig. 2.

By timing the rotation of the circular plate, *s*, so that it makes one revolution per cycle of operations, a steady and continuous discharge of solids will pass down the chute, *t*.

The first experiments were carried out in 1914 at Acrefair and Wimbledon on sewage, sewage sludge, and china clay. It was found that this type of machine was very effective for de-watering solids, but it left something to be desired with regard to the clarification of the liquor. There is always some disturbance of the lightest particles on the inner face of the deposit, and it was found that if the effluent were drawn from this area it would be polluted with solid matter in suspension at an early stage in the deposition.

The following results were obtained from a machine of this type, having a cylinder 16½ in. in diam. and 7 in. deep.

	Rate of flow, galls./min.	Influent, pts. solid per 100,000	Effluent, pts. solid per 100 000	Solids discharged, % moisture
Limed sewage ..	18	12·8	2·0	55–65
Limed sewage ..	5	38·4	3·6	55–65
Limed sludge ..	1	7100	60·0	55–65
Unlimed sludge ..	1	7000	—	65–70
Activated sludge ..	3·5	1000	—	82–85
China clay	—	10000	—	23

In order to draw the effluent from a point remote from the deposit, to increase the separating capacity to its maximum, and to reduce the power consumption when dealing with large volumes, a further development was introduced, which is described below.

"*Sturgeon*" *Centrifuge for Combined De-watering of Solids and Clarification of Liquors.*

Referring to Fig. 3, which consists of two half-sections—one through the valves in the top cover, and the other through the levers which hold the bottom cover up to its seating—the cylinder, A, has a fixed cover, B, at the top, and a movable cover, C, at the bottom. The movable cover is held on its seat by weights under centrifugal force acting through the bell-crank levers, D, which allow of a limited lift. The piston, E, which slides up and down the shaft, F, has a large hollow boss, G, through which the liquid under treatment may pass from the apertures in the hollow shaft. To the bottom portion of the boss is attached a disc or plate, H, which forms a joint with the inner edge of the movable bottom cover. Attached to the bottom cover are valve rods, K. When the piston reaches its bottom position it lifts the movable cover off its seat, thereby causing the valve rods to open the valves, L. The shaft is rotated by means of the pulley, M, and, of course, the cylinder and all parts connected thereto revolve with it.

The machine is started and the liquid to be treated enters the machine through the hollow shaft, F. It passes through the apertures into the hollow boss of the piston and thence into the cylinder. The solids are deposited on the walls of the cylinder as the liquid passes through, and the clarified liquid is discharged over the concentric weir, N, and into the chamber, O, whence it is carried away through the pipes, P. When it is time to discharge the deposited solids the supply of liquid is cut off, and water is admitted to the top side of the piston through the pipe, Y.

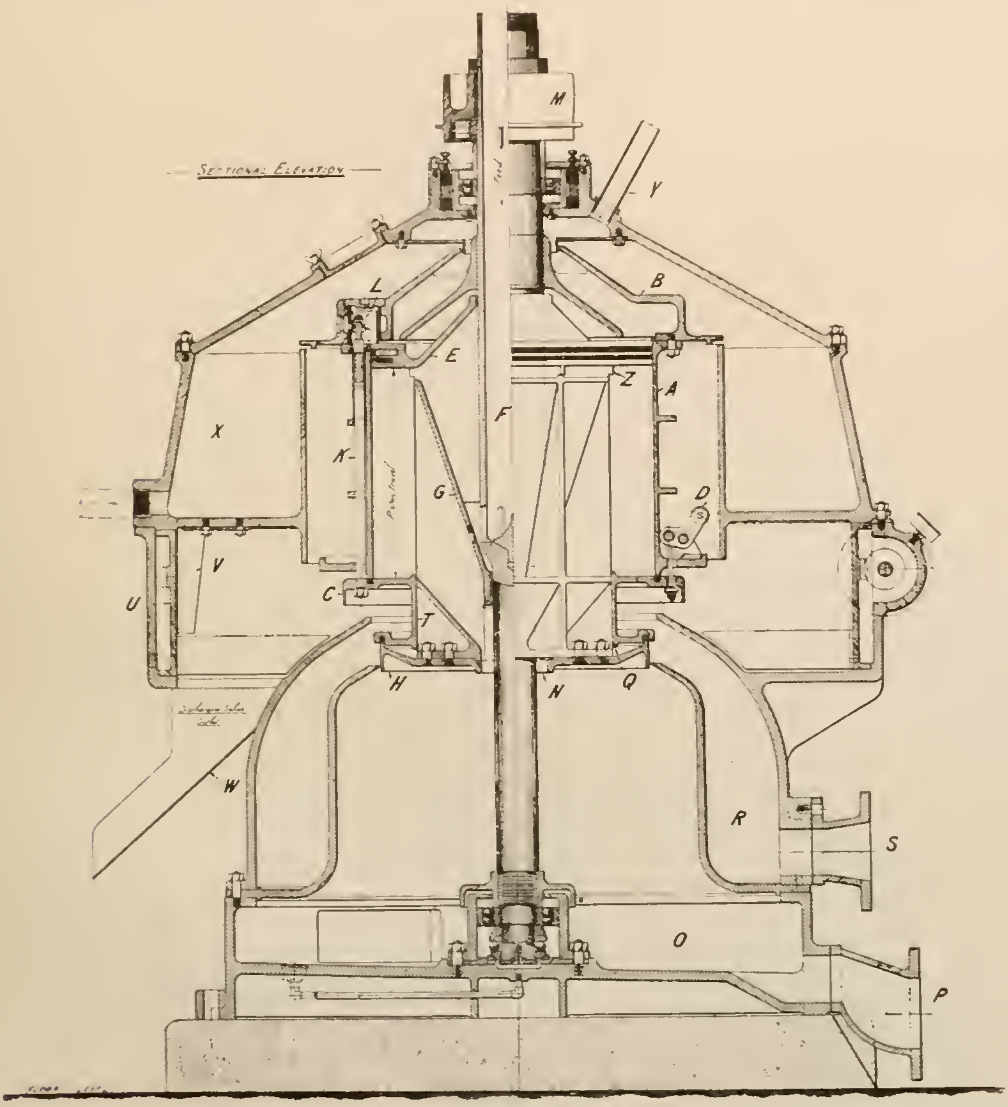


Fig. 3.

As soon as the piston commences to descend the joint near Q is broken, and the surplus liquid flows away into the trough, R, and is carried away by the pipe, S. As the piston descends the liquid continually overflows the weir, Q, until only solids are left. These are further squeezed, and much of their accompanying liquid is removed, flowing over the weir, Q. This liquid is necessarily very dirty, and is kept separate from the main effluent, which would otherwise be contaminated. Finally, the pressure under the piston becomes so great as to overcome the pull of the levers, D, and to lift the cover, C. The solids are discharged on the revolving circular plate, U, whence they are scraped off by the knife, T, and fall down the chute, W. As the cover, C, lifts the valves, L, open, and the water above the piston is discharged into the trough, X. This discharge may be made tangentially in the opposite direction to that of rotation, so that the pressure which has been imparted to the water by the machine may to a great extent be restored during the discharge. Thus the horse power required to effect the discharge of the solids is reduced to a minimum.

As soon as the pressure of the liquid falls sufficiently, the cover, C, closes, and when all the water has been discharged the machine is ready for a fresh charge of the liquid under treatment. This forces the piston up to its top position, closing the valves, L, and coming to rest on the seating, the upward pressure being sufficient to maintain the joint. The machine then fills up, and the operation proceeds as before.

In this type of machine the effluent is discharged at the maximum distance from the deposit, and the main effluent, the liquor squeezed out of the solids during discharge, the solids, and the water used for discharging are all passed into separate compartments.

The next stage in the development of the Sturgeon centrifuges dealt with cases in which clarification of the liquid is the essential factor, the amount of moisture in the solids being of small importance. In such cases a simpler type of machine than that just described can be used. A further machine was therefore constructed similar to that described below

"*Sturgeon*" *Centrifuge for Clarification of Liquors.*

The machine is shown in elevation in Fig. 4. A piston, A, is fixed to a rotating tubular spindle, B, Mounted on the piston and spindle is a sliding cylinder, *c*. Attached to the fixed piston is a cover, D, which forms a joint with the reduced open end of the cylinder. The parts all rotate in ball bearings.

The liquid to be treated enters the hollow spindle, and passing into the machine by virtue of the pressure produced in it by centrifugal force, presses the cylinder hard upon the seating of the cover, D, making a tight joint. The liquid then fills up and flows through the holes, E, down the lower half of the hollow spindle and escapes from the machine by the pipe, F. The solids are deposited on the inside wall of the cylinder, and when they have accumulated to a sufficient extent the flow of liquid is stopped and water introduced above the piston through the pipe, G. This then lifts the cylinder by means of the pressure produced in it by centrifugal force, breaking the joint at H. As the cylinder rises the water and solids are squeezed over the edge until only a small quantity is left. All the time the cylinder is being lifted the water above the piston is escaping through the leak-hole, K, but the escape is never so great as the rate of admission through the pipe, G. As an alternative to a leak-hole an automatically operated valve may be used.

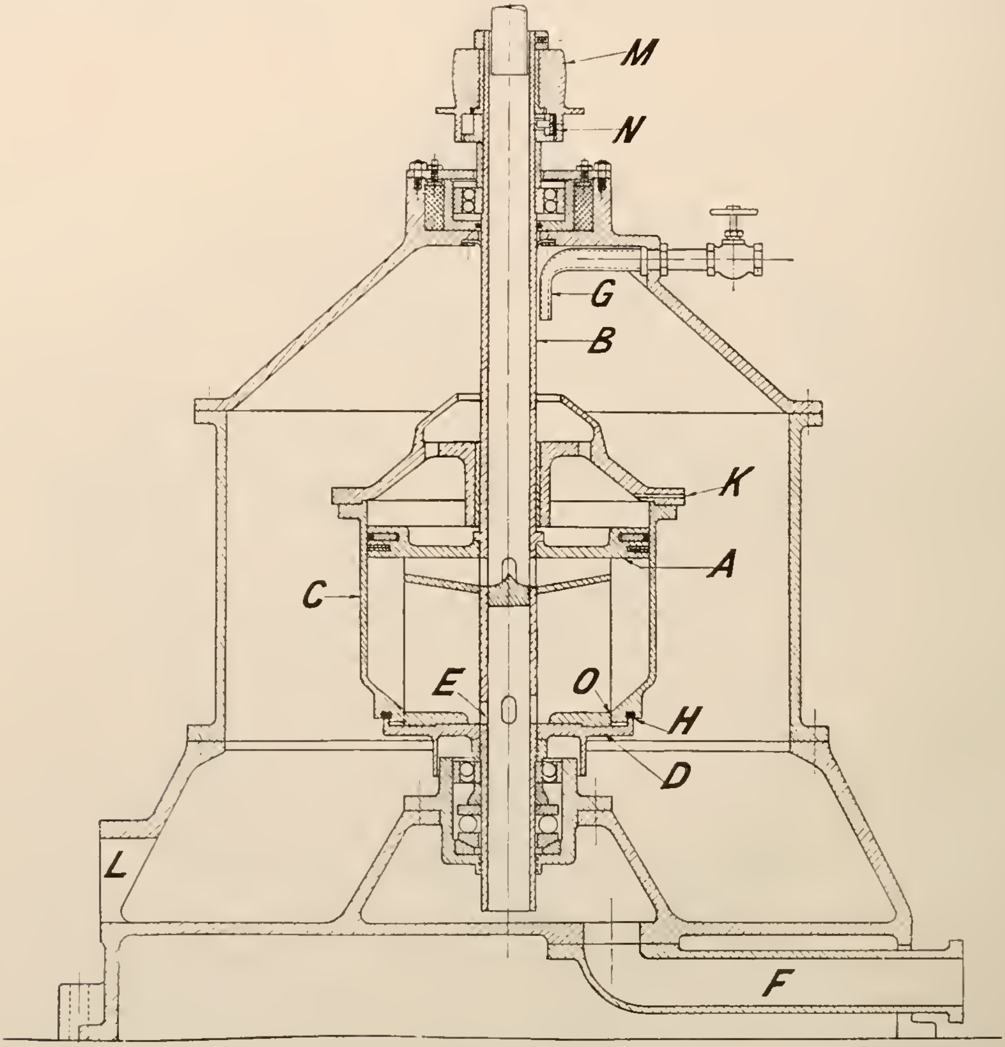


Fig. 4.

The solids that are discharged over the lip, O, are in a fluid state when mixed with the liquid held in the cylinder before discharge takes place, and will be further diluted by the water discharged through the leak-hole. They will flow from the machine through the opening, L. If desired, the water discharge from the leak-hole can be kept separate from the solids discharged from the cylinder.

As soon as discharge has taken place, the water flowing through pipe, G, is stopped, and that remaining in the cylinder is allowed to escape before the liquid under treatment is admitted. This then brings the cylinder down to its bottom position, and the operation proceeds as before. The machine is driven by the pulley, M, through the clutch, N,

Machines of this type are suitable for clarifying liquors containing soft, mucilaginous solids, which can be forced over the reduced end of the cylinder, but if the solid matter be dense, like clay, it cannot be so expelled. Such a limitation of application is, however, undesirable, especially where clarifying machines are required to deal with liquors such as wool-washings, which contain grease worth recovery, and also solid matter which is earthy and relatively very heavy (sp. gr. over 2). Thus, by the courtesy of Messrs. Jarmain and Son, of Kirkheaton, near Huddersfield, one of these machines was tried in connection with their patent process for recovering grease from wool-washings. In this process the liquor (maintained at a temperature of 180° F. during the centrifuging) is passed through a centrifuge in order to remove the bulk of the solid earthy matter (dirt), and is afterwards treated in a second centrifuge of small diameter running at a high speed so as to extract the grease. Without the preliminary treatment the small centrifuges are so rapidly choked with dirt that they have to be stopped before they have recovered any grease.

An ordinary centrifuge, 42 in. diam., running at 1200 r.p.m., is used for the roughing process. The effluent passes on to three Sharples centrifuges, running at 17,000 r.p.m., which recover practically the whole of the free grease in the liquor.

The Sturgeon centrifuge, tried in place of the 42-in. machine, had a cylinder 15 in. diam. and 13 in. deep, and the following results were obtained in comparison with the other machine:—

The relative separating efficiency was judged by the length of time the Sharples machine would run without choking, for as much of the solid matter is present as an emulsion, no amount of centri-

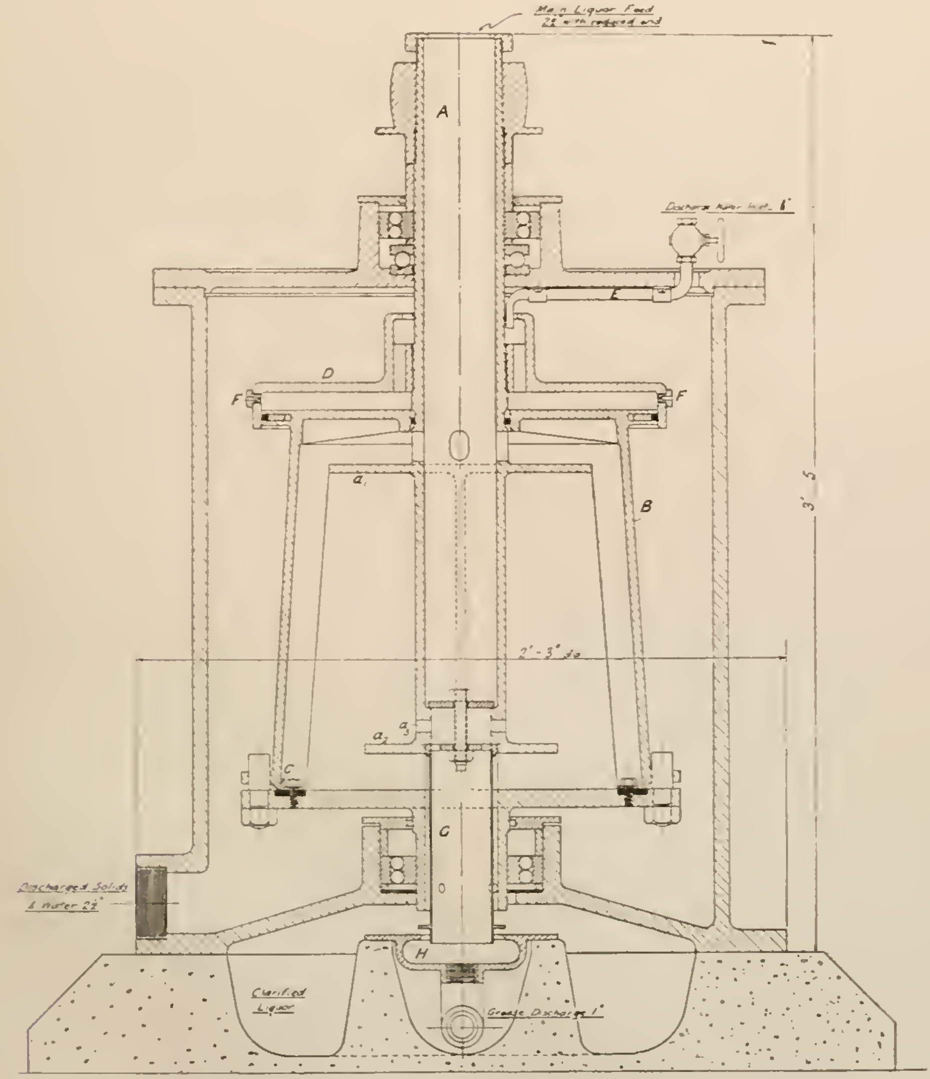


FIG. 5.

fuging will completely clear it. When using the 42-in. machine, with its overflow at a distance of about 15 in. from the axis of the machine, the Sharples machine would run for about 20—24 hrs. before choking. The Sturgeon centrifuge, running at 2000 r.p.m., would run for about 40 hrs., thus demonstrating the great advantage of the overflow near the axis.

With both machines dealing with 300 galls. of liquor per hour the Sturgeon machine took about one-fifth of the power required by the 42-in. machine, namely, 1½ h.p. instead of 8 h.p.

Regarding the discharge of the solids, the 42-in. centrifuge had to be stopped every two hours and the solids swilled out. The water used for this purpose had to be withdrawn from the machine by means of a suction pipe. The total time taken over the discharging operation was about half an hour. The discharge of the Sturgeon machine was effected every half-hour by simply turning on a valve, without stopping the machine, and the discharge required about one minute. Owing to the heavy nature of the solids, for which this type of machine, with the reduced open end of the cylinder, is not adapted, the discharges were not complete. Nevertheless, the general results were so encouraging that a modified centrifuge was designed, and is now under construction, in which this special difficulty of discharging the heavy dirt is overcome. This machine is described below.

"Sturgeon" Centrifuge for Clarification and Grease Recovery.

This machine (see Fig. 5) consists mainly of a hollow rotating shaft, A, through which liquor flows into a cylinder, B. The cylinder is kept on its seating, C, by means of water pressure (induced by centrifugal force) in the upper dome, D. The water which is used for this purpose is fed continuously during separation through the pipe, E, and escapes by the small leak-holes, F. The upper flange of the main cylinder, B, forms a piston working in the dome, D. The liquor on its passage through B deposits solid matter on the inside wall of B. Any free grease will collect between the flanges, a_1 and a_2, and overflow through the hole, a_3, down the grease tube, G, and into the grease catcher, H, from which it is collected. The clarified liquor passes away through the annular space between the grease tube and the bore of the spindle at the bottom, whence it is thrown into the collecting chamber in the foundation. When it is desired to discharge the solid deposit the water valve is turned off, and the water, escaping through the leak-holes, so reduces the pressure which holds down the cylinder, B, that the pressure in B causes a sudden lift, leaving a small clear space between the bottom edge of the cylinder and its seating. The solids are then swilled out through this opening by means of a flow of water or the continued flow of the liquor under treatment. When the solids have all been removed water is again admitted through the pipe, E, and the cylinder, B, returns to its original position.

When the liquor under treatment is used for swilling out the centrifuge the only action required to operate the discharge and to return the cylinder to its separating position is the turning on and off of a ⅜-in. valve.

By removing the grease tube, G, and the grease catcher, H, and drilling through the flange, a_2, the machine may be used for separating a simple liquor.

Centrifugal clarifiers and de-watering machines are capable of so many industrial applications that it appeared at first as though a large number of different types of centrifuges would be necessary to meet all requirements. From a manufacturing point of view this was a great disadvantage, and it was decided to design the machine on standardised lines in such a manner that it is easy, by the addition or subtraction of one or more simple parts, to produce centrifuges capable of dealing with almost any problem which is likely to arise, including the clarification of liquors, de-watering of solids, grease recovery, grading, etc., and combinations of any of these. This general machine does not differ in any essential principles from those previously described, but it has the great advantage of being readily modified so as to suit special requirements.

As this is the first time a description of these machines has been read before a public body, and many investigations are in hand in connection with its use in certain industries, it is proposed to defer the publication of full details of output, cost of running, and similar data until figures can be given on the basis of a long period of continuous running under working conditions. The data given below are, however, available for publication.

The power required by the machines may be divided into two parts—(1) that required to maintain the machine at a given speed when no flow of liquid is passing through it (this is constant for a given speed), and (2) that due to the flow of liquid through the machine, which is approximately proportional to the flow.

It is highly advantageous, when dealing with large volumes, to discharge the effluent at the minimum speed, *i.e.*, as near to the axis as possible. The power (ignoring eddy losses) is directly proportional to the square of the velocity of discharge, and is therefore approximately proportional to the square of the radius of discharge.

In the 15-in. "Sturgeon" clarifying machine, described above, the power required, ignoring eddy losses, with the machine running at 2000 r.p.m. and discharging at a radius of 1½ in., will be 0·26 h.p. per 5000 galls. per hour. The eddy losses may double this figure, giving a power consumption of approximately ½ h.p. per 5000 galls. The actual maximum flow through a machine of this size would be about this figure. The friction horse power would be about 1½ h.p., the total power working out at about 2 h.p. If the discharge took place at a radius of 6 in. from the axis the power required for accelerating the liquid would be about 4·3, making a total of about 7 h.p., allowing for friction and eddy losses. The power consumed is therefore more than three times as great with the discharge at 6 in. radius as it is at 1½ in. radius. This is, of course, a very serious matter when dealing with large volumes.

The output of solids is dependent on the time taken to obtain a full discharge of deposit, as this time controls the frequency of the discharges. The rate of deposition depends on the nature of the solids, the proportion present in the liquor, and the rate at which the latter can be passed through the centrifuge. It is impossible to generalise, as any given case must be judged entirely on its merits, but a concrete example may be given to show the method of dealing with a specific case.

Tests on a large scale are now being carried out in connexion with the application of the "Sturgeon" centrifuge to the paper industry, and as an instance of what may be expected it may be assumed that a certain effluent from a paper mill contains 400 parts of solid matter in suspension per 100,000 parts of effluent. If this be treated in a "Sturgeon" centrifuge with a separating cylinder 30 in. in diam. and 20 in. deep on a 10 seconds basis (that is, one complete filling of the centrifuge with the liquor every 10 secs.), the deposit of solids reaching a thickness of 2 in. before a discharge is required, and the solid matter containing, while in the machine, about 60% moisture:—

The rate of flow works out at about 330 galls. per min., and 1330 galls. will flow through the machine before the full deposit is made. That is to say, the liquid will be flowing for 1330/330=4 min. between each discharge. Assuming that the discharging operation takes one minute, it will be possible to obtain 12 discharges per hour. The net result is therefore:—Volume dealt with per hour, 16,000 galls.; weight of solids, measured dry, 640 lb. per hour; weight of solids, as 60% cake, 1600 lb. per hour.

The present value of the paper pulp recovered from the effluent will be at least 1d. per lb., so that the value of the solid matter regained, which would otherwise have gone to waste, would be about £2 10s. per hour, or say, £5000 per annum. The cost of a machine to do this work would be about £1200.

The degree of clarification depends on the proportion and nature of the suspended solids, the rate at which the liquid is passed through the centrifuge, and the precautions taken to reduce eddies to a minimum. The following results were obtained from a 15-in. "Sturgeon" centrifuge with an overflow near the axis, the liquor containing a mixture of magnesium and sodium carbonates (such as is used for water softening) in various degrees of concentration. The solid matter was very light, flocculent and finely divided:—

At 2000 r.p.m., rate of flow, 10 galls. per min.; influent, 430 pts. solids in suspension per 100,000; effluent, 23·3 pts., or 94·6% clarification.

At 2000 r.p.m., rate of flow, 28 galls. per min.: influent, 16 pts. solids in suspension per 100,000; effluent, 2 pts., or 87½% clarification.

At 2500 r.p.m., rate of flow, 10 galls. per min.: (*a*) influent, 540 pts. solids in suspension per 100,000; effluent, 18·5 pts., or 96·6% clarification; (*b*) influent, 1860 pts. solids in suspension per 100,000; effluent, 30·2 pts., or 98·4% clarification.

The effect of the speed of rotation on clarification will be noted. Where a high degree of clarification is necessary it is of importance to obtain the maximum speed of revolution. On the other hand, there is little advantage to be gained in de-watering problems by increasing the speed beyond a certain point. In such cases the working speed should be that which will give the desired result and no more.

With reference to automatic time control of the discharging gear, a simple apparatus has been designed, with an adjustable control, which will enable the whole centrifuge plant to be run by mechanical means. This, in combination with the self-discharging properties of these centrifuges, will enable the whole of the liquor and solid matter passing through the machines to be handled mechanically and automatically.

There is a vast field for self-discharging centrifuges for dealing with fine solids. Fresh applications are continually being brought forward. It has been demonstrated that direct centrifuging in one stage will deal with large volumes of liquors containing up to 50 parts solid per 100,000 and reduce them to a state which would be accepted by the Rivers authorities. It would probably require two stages of treatment of thick liquors to obtain a similar standard.

Where a filtration standard is required, and large volumes have to be dealt with, these centrifuges can be used advantageously for a preliminary roughing treatment, in which well over 90% of the solid matter may be removed in a short time, and the effluent can be passed on to a suitable filter. Where purification is required, such as with sewage or offensive effluents, a "Sturgeon" centrifuge, worked in conjunction with one of the well-known mechanical filters, will give results which it is impossible to achieve by any single mechanical unit, and with greater economy than is obtainable with any other mechanical combination.

The possibilities and usefulness of the "Sturgeon" centrifuge have only been briefly outlined, and further investigations are now being made in order to combine in one machine the virtues of great capacity, low power consumption, and the highest filtration standard of clarification.

The introduction of a continuous-running, self-discharging centrifuge, which combines the above qualities to the extent in which they are found in the "Sturgeon" centrifuge, cannot fail to make a great impression on the chemical industry as well as on other branches of industrial enterprise and public works. The main advantages of continuous-running, self-discharging centrifuges over intermittent running centrifuges are obvious. They may be summarised as follows:—

(1) *Saving in labour.*—As the discharging operation can be effected entirely by mechanical control, there will be a substantial saving in labour costs.

In the second place, where the material dealt with is unpleasant to handle, which is generally the case in dealing with waste material, the labour necessary to operate intermittent machines is likely to be extremely difficult to obtain. This difficulty has certainly prevented a more extended use of intermittent-running centrifuges in this direction.

In the third place, where the material is of a dangerous character, poisonous or explosive, it may be absolutely impossible to use an intermittent-running centrifuge.

(2) *Increased output.*—As the interval required to effect discharge of the deposited solids is of the order of one minute in the continuous-running centrifuge, compared with 20 minutes to half an hour for the intermittent-running machine, it is obvious that the former will have a greater output for a given size of machine than the latter. The shorter the time required for separation, the more serious is the time lost in extracting the solids. Thus, a continuous-running centrifuge may obtain 15 to 20 discharges per hour, against 2 or 3 for the intermittent-running machine.

(3) *Saving in power.*—Provision has to be made in the case of intermittent-running centrifuges for a substantial margin of power to enable them to pick up speed rapidly after discharging. Apart from the heavy consumption of power during the speeding-up, the power unit is then run at, perhaps, half load, or less, with a resulting loss in efficiency.

I should like to take this opportunity of recognising publicly the great help we have received from many people in the development of this invention. In particular, I cannot refrain from referring to Dr. W. O. Travis, with whom I collaborated in the early stages; Messrs. Hughes and Lancaster, of Ruabon, and Messrs. Thomas Broadbent and Sons, of Huddersfield, in the manufacture of the experimental machines; Messrs. Jones and Attwood and the Manchester Sewage Authorities, Messrs. Jarmain and Sons, Kirkheaton, and Messrs. Peter Dixon and Sons, Grimsby, who have given most valuable facilities for testing machines at their works.

In conclusion, I wish to thank the Chemical Engineering Group for their kindness in allowing me to bring this subject before you to-day.

DISCUSSION.

The CHAIRMAN (Prof. Henry Louis, D.Sc.) opened the discussion by remarking that although the action of the centrifuge was not what he might call within the restricted definition of filtration, yet it formed an important adjunct to a number of processes, as they knew, in chemical and chemico-metallurgical operations. They had all stages of the separation of liquids and solids, from the "thickeners," as they were called in America, by which a certain amount of fluid was got rid of, up to the fast form of filtration. These centrifugal machines would play an important part in the complete review of the subject.

Mr. F. **Sproxton** asked if the centrifuge would be suitable where the suspended matter was of a fibrous nature.

Mr. H. M. **Ridge** said he was sure they all appreciated the advances which had been made in the use of centrifuges, but he would like to ask the author how far he had really carried out the use of this machine—whether it was in the experimental stages or whether it had been put into regular use in works. If so, he would like to inquire a little further—he did not want to make an adverse criticism, because anything done in this direction was extremely valuable for the future—but he would like to ask whether the author had not had difficulty in keeping the pipe in the figure on page 3 tight, and whether he had had any experience of being able to run the machine continuously, or whether he had had any mechanical troubles.

Mr. R. A. **Bellwood** asked if the machine was suitable for a semi-liquid containing, say, a large percentage of solids—anything bearing from 50 to 80 per cent. of solids. He took it from the remarks made that it was suitable for liquids containing a small percentage of solids.

Mr. **Leslie** H. **Lampitt** said he had been making experiments on centrifugal separations of liquids which had to be kept warm—cases which involved the separation of solid matter from fatty substances. They had absolutely failed. They had been able to effect separation, but the output had been so slow and so little that economically it had been unsound. The specific gravity of the liquid, the effluent, was about ·92 to ·95, and the specific gravity of the solid, which was more or less gelatinous, was about 1·25. Had the author of the paper done any experiments on liquids and solids of that nature? He could assure the author that if he had, and with success, there would be quite a big opening for such a machine.

Mr. F. R. **O'Shaughnessy** remarked that the author stated that he had made experiments with this machine on sewage liquors. He wondered if the author had done it on such a large scale as to be able to give particulars with regard to cost.

Mr. R. E. **Jackson** asked for some idea of the different materials the machine was used for. It seemed to him that the pressure which had to be applied each time would be different with each different material used.

Mr. **Alan** V. **Rhead** enquired what was the percentage of water required for removal of the cake, and also the rate of filtration. Possibly the author could say how long it took to separate a thousand gallons, and also whether there was any possibility of recovering the cake as a cake. This was so essential in many filtration problems where the cake was of more use than the liquids. How would it be possible to obtain Ferric Oxide in a commercial form, for example?

Dr. L. F. **Goodwin** said he would like to ask one question which had been partly put by a previous speaker, and which might give them a good deal of information. There were many types of either centrifuges or other filtering devices, and perhaps what those present wanted to know was what were the limits within which they could be used. Could the author tell them up to what percentage of solid to liquid he thought the Sturgeon centrifuge was economical? It would give them an idea. Would it be economical up to 10 or 30 per cent., as the author had probably discovered this limit. On the other side, speaking with all diffidence, he thought it would not be suitable for a very fine separation. There must be two limits within which the author could recommend the machine. The standpoint of cost was also important.

Mr. W. J. **Palmer** said that, assuming they had an homogeneous mixture of several substances of different specific gravities, would this machine differentiate between the different solids as regards specific gravity. Also, assuming they had a solid of varying specific gravity of 3·4 to 4, what would be the average of moisture in the discharge.

Mr. A. E. **Malpas** said that, looking at Fig. 1, which was the only one he had really had time to examine, one must congratulate the inventor on his boldness in tackling a problem of that sort in the way he had adopted. They had all had something to do with centrifugal machines at different times, and they were fearsome things at the best of times. The inventor had evidently designed the machine for handling colloids, by which he took it was meant solid matter in a finely-divided state held in suspension in a liquid more or less dense. These finely-divided precipitates—it was generally a question of precipitates—had given a lot of trouble in separating, and he had always understood that the finer the particle the higher the speed of the machine should be in order to separate them. He did not know whether the author mentioned at what speed this machine was supposed to run. He had a suspicion that he heard about 1000 revolutions with a 36-in. diameter. Early in the war he (Mr. Malpas) first came in practical contact with this question of separating a precipitate which was very fine from a liquid which was very dense, and stuff that would not settle at all well, and in desperation they finally dropped on Mr. Gee's separators, which were being used in Cornwall for grading china clay into different sizes. They managed to commandeer a small machine of this type. He thought the speed was something like 5000 revolutions, and the first time they put it down it shook the foundations to pieces, and then they lowered it below ground in case it killed anybody. But every time it started there was somebody who was very nervous about it. They had seen from the samples exhibited that some measure of success had been obtained with speeds of 1000 revolutions with a 36-in. basket, but even with 1000 revolutions on a 36-in. basket one had this anxiety—the vibrations that were set up. Each machine had a critical speed depending on its own weight and balance which set up dangerous vibrations, and looking at the sketch of the machine, they saw rather a large number of loose parts which, after a short time working, one would expect to wear and set up a good deal of rattling. The water valves one would not expect to remain tight for very long, and one would expect some of the collodial precipitate to find its way downwards under the piston and block the piston. So he would like the inventor to say how long he had been able to run one of these machines without taking the whole to pieces and having it thoroughly cleaned.

Capt. C. J. **Goodwin** said there was one point he would like to raise in connection with this machine, and particularly in regard to the paper. Chemical engineers as a body were glad to get facts, and facts in regard to what the performance of the machine was, and Mr. Sturgeon had been good in that respect and had given them exceedingly useful figures. There was one question he did not seem to have touched upon, and that was the question of the temperature at which filtration or separation took place in this case. It was a fairly well-known fact that in ordinary sedimentation tanks, as distinguished from this machine in which the use of centrifugal force was employed, the rate of sedimentation was considerably greater at higher temperatures. The author would be doing a service to chemical engineers if he could have made some investigations with regard to the effect of increase of temperature on the rate of separation for various materials.

Mr. Sturgeon, replying to Mr. Sproxton, said the machine was quite suitable for treating fibrous materials, if the fibres were not more than ¼ in. long. Should they be longer than this, special arrangements would have to be made. There would be no difficulty in doing this. In reply to Mr. Ridge, the machine has only just passed through the experimental stage, and has not yet been used in works practice on an extended basis, although work on these lines is in hand. With reference to the water-feed pipe in Figs. 1 and 2, it is not necessary to keep a tight joint, as there is no water pressure at the centre of the machine. The water pressure in the pipe need only be sufficient to carry the water into the machine, and there can be an air space all round this feed pipe. Up to the present the machines had only been running intermittently, but this was sufficient to make it perfectly clear that there was nothing to fear from continuous and extended running. As was to be expected in any new departure of this kind, certain faults and limitations have shown themselves from time to time, but these are all troubles which can be overcome by care in design. Referring to Mr. Bellwood's and Dr. Goodwin's queries, the only requirement in dealing with thick liquors is that they shall be able to flow into the machine. The question as to whether it is profitable or economical to treat such liquors, depends entirely on the individual case. The limiting point will vary with practically every material. Referring to Mr. Lampitt's question, the separation of solids from fats is done successfully in the treatment of woolwashings, which is described in tho paper. In certain cases the solid matter may form an emulsion with the fat and be extremely difficult to treat. In such cases it is sometimes necessary to give a double treatment, finishing in a very high speed centrifuge. Answering Mr. O'Shaughnessy, most of the early experiments were carried out on sewage liquors, with very encouraging results. Nothing had yet been done on a large scale, but it is possible to give approximate estimates as to what may be expected, both as to running costs and efficiency of working. Mr. Jackson thought that adjustments would have to be made with every different class of material. It has been found possible to treat a great variety of materials in the same machine, where the specific gravity of the solids has ranged from 1·2 to over 2, without altering any adjustments, provided the general result required was the same. Mr. Rhead wishes to know what percentage of water is required to effect discharge. This amount is proportionate to the volume of solids discharged, and is approximately equal to one cylinder-full per discharge. The standard machine discharges the solids as a cake, and it is the volume of this cake which forms a basis for estimating the volume of water required to effect discharge. The permissible volume of the cake will vary with its weight and the size of the machine. With a 30″ cylinder, a 2″ to 3″ thickness of deposit would be permissible. The rate of filtration or separation depends entirely on the nature and proportion of the solids, and the standard of clarification required. Some figures are given in the paper which indicate the results of tests in which the rate of feed and proportion of the solids are varied. The centrifuge is well adapted for the recovery of precipitates. In reply to Mr. Palmer, the standard machine would mix the separated solids. The development of a grading machine has been considered, but has not yet been put in hand. Referring to the remarks of Mr. Malpas, the first experimental machine was completed in 1914, and has been used intermittently for a large number of tests. There had been no trouble with vibration; in fact, in a seven hours test two pennies had remained balanced on the top of the casing of the machine throughout all the stages of the operations of starting, charging, discharging, and stopping. It has been found that with the double bearing and a sufficiently rigid shaft, there is no vibration, but if the shaft be too light, so as to allow it to whip, there will be trouble. In the machine referred to above there is not the slightest sign of wear in the pins and bushes of the levers. There is really no reason why there should be, as the machine runs steadily, and the bearing loads and stresses are well within standard practice for engine work. They are made of good-class mild steel, case-hardened. The levers and valve rods are made of duralumin, for the sake of lightness combined with strength. The possibility of fine colloidal solids finding their way past the piston was considered, and steps were taken in the later design shown on Fig. 3 to so arrange the valves that they could be removed readily without dismantling the machine. No trouble has been experienced of their becoming fouled, and it must be remembered that only very fine solids can get past the piston should the joint ring be leaky, and, in any case, the valves and that side of the piston are very thoroughly swilled out with clean water every time the solids are discharged. Captain Goodwin raised the question of the effect of high temperature on separation. A great deal has yet to be done in this direction, although there is evidence to show that improved results may be expected in certain cases by increasing the temperature of the liquor under treatment. To give an example, in the treatment of a certain difficult material at normal temperatures the moisture content of the discharged solids varied between 82 and 85 per cent. By raising the temperature to 80° C. they were reduced to 79 per cent. The effect on the effluent was not observed. Working at a moderately high temperature has been found of great assistance in the case of wool-washings, which could not otherwise be treated with any advantage by means of centrifugal action.

The Chairman, in moving a hearty vote of thanks to Mr. Sturgeon for his paper, said he had been very much struck by the extremely capable way in which the author had been able to answer a wide variety of questions on many diverse points. The Sturgeon machine undoubtedly had a great future before it, and the meeting was particularly grateful to Mr. Sturgeon for the able presentation of his paper.

DESIGN OF MECHANICAL FILTER.

BY BALFOUR BRAMWELL.

This short paper consists of some remarks on the design of mechanical filters, on the development of this type of filter, some information of their working obtained over many years' experience, and some brief remarks on the different apparatus provided for the cleansing of the filter bed, especially those with reference to filters at present in use.

The So-called Mechanical Filter.—The so-called mechanical filter probably receives its name on account of its contrast to the common large area slow sand bed. The slow sand beds are entirely of masonry construction, except for the valves, pipes, and fittings, whereas the mechanical filter is usually constructed of either steel or iron, and generally embodies designs of a mechanical nature provided for the process of cleansing of the bed. Slow sand beds are always open under atmospheric pressures, whereas filters are made both open and closed, the closed ones working under pressure of water in main supply pipe.

The principal difference in filtration between the mechanical filter and the slow sand-bed is in the speed of filtering. In the mechanical filter this speed is approximately 40 times that of the slow sand bed, consequently tho mechanical filters are often termed rapid filters to distinguish them from slow sand beds.

Process of Filtration.—The actual process of filtration in all water filters is principally a straining action. In the slow sand bed this action is more dependent on the natural impurities strained out of the water, whereas in the rapid filters the action is almost invariably assisted by chemical precipitation treatment.

There is, however, a great difference in the way this straining action is carried out in the slow sand bed and the rapid mechanical filter.

In the slow sand bed the straining action is confined almost entirely to a thin top layer of the filtering material, whereas in the rapid filter the whole depth of bed is made use of before the filter is thrown out of action for the cleaning process.

In the slow sand bed, when it is once in condition, the impurities are arrested on practically only ½ inch of filtering material at the top, but in the rapid filter the impurities penetrate the bed in a gradually decreasing amount, and if a filter is kept too long in action or pressed to much the impurities begin to come through. Signs of this are always easily visible in a noticeable falling off in the appearance of the filtrate; a dulness of the filtrate is quite perceptible when examined in a 3 ft. tube.

What must be aimed at in determining the capacity of a filter to deal with a certain water, the maximum allowable loss of head, and the length of period between the times of cleansing is that the maximum loss of head allowed shall not be reached before there is any sign of the impurities coming through the bed.

Slow sand beds generally work for months without scraping, but the rapid mechanical filters are usually designed so that the cleansing process is carried out in the case of waterworks once per 24 hours, or sometimes once every 12 hours, and in the case of filters for industrial purposes once per working day, or in some cases once every 6 hours. The author recommends that the former periods be always worked to, that is to say, once per 24 hours for waterworks filters, and once per working day for industrial filters.

The usual speed of filtration for slow sand beds is approximately 2½ galls. per sq. ft. of superficial area, whereas the most economical and satisfactory speed for design of mechanical rapid filters is 100 galls. per sq. ft. when dealing with the purification of ordinary average waters met with. With a better class of water this speed can be increased 20%, and it is not uncommon, but cannot be recommended, to have filters that are being cleansed every 6 hours working at a speed of 140 galls. per sq. ft. When the water to be purified is very good, and requires very little chemical treatment, the speed of filtration can be increased two or three times, but it is rare that such waters are met with except under exceptional circumstances.

Filming on Bed.—The common theory of surface film on a filter is very misleading, and certainly not at all applicable to rapid filtration. It may apply somewhat to a slow sand bed where the straining action is confined almost entirely to the surface of the bed, but it certainly does not apply to a rapid filter. There is no doubt that slow sand beds are much more sensitive than rapid filters, and this sensitiveness in the slow sand beds is due to the fact that the straining action is confined to such a thin layer of filtering material. The filtering material in slow sand beds is usually of a finer grade than in the mechanical filter.

It has been said that minnows getting on to a slow sand filter have seriously affected the filtrate, presumably by disturbing the film. The theory may be correct in a slow sand bed, but to prove that it is entirely erroneous in the case of rapid filters it can be shown that an agitation of the surface of the filter bed is often advantageous. An illustration of this is best given by an account of some filters that were installed at a large paper works in Scotland for the purpose of clarifying and decolorising peat-stained river water, the filtrate being used for the manufacture of white paper. On the river above the works where these filters were installed were other similar works, which discharged their effluent into the river. After the filters were started it was found that the loss of head was high and rose very quickly, and the period between the times of cleansing was much shorter than what would normally be expected. The filter bed was examined without performing the cleansing operation, and it was found that the impurities were arrested almost entirely on the surface of the bed, and did not penetrate it to any extent. On examination of the impurities it was found that they consisted largely of esparto grass fibre in a very finely divided state. It could only be seen in a glass of water by holding it up to the light, and then these fine, hair-like impurities could be seen to be glistening in the water. The filter bed, without having the cleansing operation performed, was allowed to dry, and a layer of the impurities, resembling a sheet of brown paper, could be skimmed off the top of the bed.

Reversing the flow of water through the bed for short periods during the run reduced the loss of head considerably. After the filters had been at work some time the bed was made of a coarser grade, with much improved results.

Example of Surface Agitation of Bed.—Again, as a further example of surface agitation, there is the filter at present in use known as the drifting sand filter. There is no doubt that with this system of cleansing the periods between the times of cleansing are somewhat lengthened, but cleansing of the whole bed from top to bottom is just as necessary with this system as with any other rapid filter, and must be carried out with the drifting sand filter at periodic intervals, so that it cannot be claimed that the system is a continuous cleansing one.

I have considered it necessary to introduce my subject of design of mechanical filters by these few preliminary remarks on filtration in general. A great deal more can be said on the subject, but what I particularly wish to emphasise is the fact, and I think it is generally accepted, that in order to get the best results from rapid filters chemical and coagulant treatment must be used.

Chemical Treatment.—In the early days of rapid filtration there was considerable prejudice against chemical treatment, even by the medical profession.

I am, however, glad to say that now this prejudice has entirely disappeared, and one seldom hears of any objection to the chemical treatment of drinking water. As a matter of fact, chemical treatment is generally beneficial to the water from a potable point of view, and many cases can be given now of waterworks where chemical treatment is given to the water even without filtration. Provided sufficient time is given for storage and for the chemical action, precipitation, and sedimentation to take place, there is, of course, no need for filtration. In our days, however, it is a mistake to build huge reservoirs for the purpose of storing water to obtain purification when this purification can be achieved by quite a short storage and rapid filtration, for instead of months of time for the process only hours are required with subsequent rapid filtration. It is entirely wrong, however, to depend too much for purification on chemical treatment. Want of filtration or inefficient filtration often means overdosing with a germicide to obtain the necessary result.

Order of Treatment.—Drinking water should be first clarified by efficient filtration, and sterilisation should be effected after clarification if possible. It is of absolute importance in the purification of drinking water to have efficient filtration.

The reason for this order of treatment is very marked, and that is the quantity of a dose of the germicide depends very greatly on the turbidity of the water, so that it is most uneconomical to attempt to sterilise turbid water by the use of a germicide, and I believe I am correct in saying that this applies to other methods of sterilising such as by using ultra-violet rays or ozone.

Function of a Filter.—The function of a filter is to arrest impurities in the water and to allow the water to pass freely through. The most efficient filter is, therefore, the one in which the bed holds the impurities and gets dirty, and the best filter is the one which can do this and has a cleansing process that restores the bed each time the operation is performed to its original state. It is, therefore, quite evident that everything depends on the cleansing process. There are, of course, other considerations, but the most important one is an efficient cleansing of the bed as uniformly through the whole depth as it is possible to carry out. The cleansing also must be complete from top to bottom.

The cleansing of the filter bed is a very important operation. At every periodic cleansing of a mechanical filter the whole bed should be disturbed and uniformly agitated and cleansed from top to bottom. In all mechanical filters, with one exception, this is effected by a voluminous reverse flow of water, which lifts and eases the bed before the agitating devices operate. The exception is the filter working on the "turn-over" principle, in which the whole chamber is made to revolve slowly. Unless this is done with absolute uniformly some of the impurities are left behind in certain portions of the bed, and over extended periods of working these impurities accumulate and form dirty spots in the bed. Decomposition of some of these impurities takes place, and the filtrate is affected. Such effects are not so easily visible when dealing with comparatively good waters, but when filters are used for purifying really bad waters the difficulties become much more apparent, especially after the filters have been at work some years, and it is after years of use that the good points in design of a mechanical filter are appreciated.

Methods of Cleansing.—To the casual observer, when examining the various methods of cleansing in the several successfully operated filters in use, each has to all appearances some distinctive design. One may have revolving arms or rakes for agitating the filtering material, another may have a revolving impeller, others may use steam or compressed air injectors for agitating the filtering material, or another might have continuous sand ejectors. It is, however, interesting to note that every one of these filters with all these different devices are all dependent for their successful operation in effecting a complete cleansing of the bed on a voluminous reverse flow of water, the effect of this reverse flow being to lift and ease the bed before the various agitating devices can be put into action. There is really only one filter in existence in which the breaking up of the whole bed is accomplished by other means than those I have mentioned, and hat filter is on the "turn-over" principle. In it the whole chamber is made to revolve slowly, like a sand or ore washer or any common revolving washing machine.

In all the other filters the reverse flow has to be concentrated by means of restricted orifices, and without such reverse flow under a considerable pressure cleansing cannot be efficiently effected. In the case of air or steam injectors it has been found that a reverse flow of air or steam through the bed is useless without a voluminous supply of water. The effect of blowing steam or air through a filter bed gives the impression, when looking down on to the water, of a great agitation, but, as a matter of fact, it is only a surface agitation of the water. It requires voluminous reverse flow of water along with the steam or air.

In the "turn-over" filter, by revolving the whole of the filter chamber to upset the whole filtering material only a comparatively slight reverse flow of water is necessary to wash the impurities to the surface of the bed. The following are features affecting the efficiency of cleansing, for it cannot be disputed that the method adopted for the cleansing is really the crucial feature in the mechanical filter. With the "turn-over" principle there are no nozzles in the bottom of the filter. The bed rests merely on a double thickness of perforated plates with holes superposing, having sandwiched in between them a fine mesh of strong copper or bronze gauze. The area, therefore, through the bottom is nearly equal to the area through the perforated plates, and is very large. The gauze is well supported, and only exposed in the perforations, which are half an inch diameter. There is, therefore, no restriction to the passage of water, and practically no loss of head from this cause.

Features of Design in the Cleansing Methods adopted.—In all filters which depend on a voluminous reverse flow of water to lift and ease the filter bed, nozzles and restricted openings are required to concentrate and give force to the reverse flow of water. These restricted openings have a tendency to fur up and clog, and they tend to increase the loss of head in the filter.

Rakes or Revolving Arms.—Rakes, revolving arms, or impellers for the purpose of agitating the filtering material inside the filter have the usual disadvantage appertaining to a machine having moving parts out of sight which cannot be lubricated or examined and are subject to both erosion and corrosion.

Steam or Compressed Air.—The disadvantage of filters using steam or compressed air injectors is that steam is seldom available except in industrial installations, and compressed air requires special machinery to produce it, and is costly. The main disadvantage, however, is that it is not so efficient.

Filters depending on reverse flow of water under high head for cleansing necessitate the provision of this water under the necessary head, and as a rule there are difficulties in obtaining the head.

Filters on Pipe Line.—Filters coupled direct on unbroken pipe lines in the first place cost a great deal more, for two reasons. They usually have to be made to suit a high pressure, and, secondly, their capacity must be such that they are capable of dealing with the maximum hourly consumption instead of an average hourly consumption over 24 hours when a balancing tank is provided.

In filters subjected to high pressure all the stuffing boxes require much more attention. Also, filters on pipe lines are subject to the detrimental effects of a large varying pressure, whereas low-pressure filters have considerable advantages in their operation and in the simplification of apparatus required for chemical treatment.

In rapid filters using chemical coagulant treatment the minimum depth of bed of one grade should not be less in the smallest sizes than 2 ft., and in large waterworks filters it should be from 2 ft. 6 in. to 3 ft.

When a coarse grade of material is used at the bottom it should not be reckoned as efficient material. In filters which require for their cleansing of the bed a voluminous reverse flow from nozzles, it is customary to provide about 10 to 12 in. of very coarse material at the bottom round about the nozzles in order to prevent the fine material from choking the small perforations in the nozzles, and to give a better distribution of the cleansing water, as well as a better collection of the filtered water. This 10 or 12 in. possesses no filtering value, therefore the effective depth of bed must be reckoned by the depth above this portion. It also has another objection, namely, that it never gets thoroughly agitated and cleansed, but only partially, and in consequence has a tendency to become foul.

Both in theory and practice it can be proved that a slightly coarser material on the surface and the fine material at the bottom is much better, because the larger impurities are always caught on the surface, and the surface clogs first, therefore a slightly coarser bed suffices to arrest them and produces less loss of head.

The best filtering material is undoubtedly crushed quartz, because it is hard and sharp and less liable to trituration, and is practically nonabsorbent. Natural sand gives the same filtering efficiency, but it does not clean quite so well owing to its rounded particles, neither does it pack so well. It is absorbent, and most of it is composed of a soft, triturable material. Quartz is, however, very expensive and difficult to procure at the present time.

All material, whether mechanically crushed or natural, should be free from dust or very fine particles, and should, therefore, be riddled. The grade of filtering material should, of course, be made as uniform as it is possible to obtain, but in practice absolute uniformity cannot be expected; therefore, a system of cleansing which necessitates a reverse flow of water at such a high head and of so great a volume that it throws the finer particles of the filtering material to the surface is distinctly at a disadvantage.

The bed in the " turn-over " filter is as nearly as it is practicable to supply one uniform grade throughout. What fine particles, however, are in the bed, by the system of rotating the chamber first in one direction and then in another, have a tendency to find their way to the bottom of the bed and the coarser particles to the surface, just exactly the same effect as the riddling of sand in an ordinary riddle.

Cost of Upkeep.—As regards the question of cost of upkeep, nozzles are troublesome and costly to renew. Any parts in a filter that are subject to an erosive action owing to an high speed of water have a tendency to wear by erosion, and require renewal after some years' working. Seeing that these nozzles sometimes number as many as 400 in a moderate sized filter, it is easy to realise that the renewal of them is expensive and occupies a long time, during which the filter is out of action. The simpler the filter can be made, especially internally, the better, and the writer ventures to point out that the " turn-over " principle of cleansing, although it means that the filter costs a little more to construct than many others depending principally on the reverse-flow system, still possesses great advantages, and especially has a much lower cost of upkeep and greater efficiency of cleansing. As evidence of this, it has been found repeatedly that a few minutes after the " Turn-Over " Filter has been restarted, after the cleansing operation has been completed, the filtrate is practically as good as at any other time, whereas with an imperfect cleansing system the filtrate will come dull and cloudy sometimes for hours after it has been restarted.

There is a great deal more that can be said on principles of design of mechanical filters, but in order to shorten this paper I must now pass to the actual designs of mechanical filters in present-day use.

Mechanical Design.—I propose to treat designs more or less in a diagrammatic fashion, and the figures that I have given are supposed really to represent features of design and not detail. The letters on each figure refer to similar parts.

(The figure numbers refer to slides and diagrams that will be exhibited at the meeting.)

Fig. 1 represents the common design of open filter used in America. These filter chambers can either be made in concrete or metal. The cleansing system sometimes is a reverse flow of water alone from nozzles or perforated tubes, or the agitation of the bed is sometimes assisted by revolving rakes such as shown in the illustration. Similar filters also use compressed air with the reverse flow.

Fig. 2 represents similar filter, but a closed chamber.

Figs. 3 and 4 represent respectively the designs of closed and open filters, one of the first mechanical filters used in this country, known by the name of the Reeves' Filter. It has been superseded by better designs, although in many cases was extremely successful. The patentee of this filter (deceased now a number of years) was also the joint-patentee of the first " turn-over " filter of spherical shape, and when I refer to this filter I will give the brief history of its development.

Fig. 5 is an outline view of a filter that is in use largely in this country, in which the cleansing is performed by a reverse flow assisted by revolving arms, which arms are hollow, and from which water is ejected under a high head from a number of small valves in these arms.

Fig. 6 represents a filter in use in which a steam ejector causes a current of air to mix with the reverse flow of water entering the bottom of the filter.

Fig. 7 represents a filter which, similar to all the others mentioned, is dependent on a reverse flow of water to lift and ease the bed, and when this is done an impeller draws the filtering material from the bottom and spreads it near the surface along with a stream of incoming wash water.

Fig. 8 is a diagrammatic view of what is known as the drifting sand filter.

Every one of these filters mentioned depend on a voluminous flow of cleansing water at a comparatively high head to lift and ease the filter bed before it can be agitated and broken up and the impurities washed out to the surface by the agitating devices provided for this purpose.

Figs. 9 and 10 represent the " turn-over " filter in which the author is personally interested. My remarks on this filter will be somewhat full because I, as well as many others, are absolutely satisfied that the filter possesses certain distinct advantages over any other, and only requires to become better known amongst engineers.

The design of the " turn-over " filter was the outcome of trouble experienced in imperfect cleansing of the bed in Reeves' filters when dealing with a very bad water to be used for industrial purposes, especially water containing colloid matter, of which most rivers contain a certain proportion, and which is most difficult to deal with. Unless the bed is disturbed in every portion at each periodic cleansing the tendency is for the portions imperfectly cleansed to become gummed up in such a manner that the means provided for agitation, in order to loosen and wash out the impurities, are insufficient. Rakes could not reach all the parts of the filter bed. The result of this experience was that the " turn-over " principle was thought of, and the very first filter installed is still successfully at work to-day.

The sides of the chamber in the " turn-over " filter are curved or spherical, and have the same beneficial packing effect that cone sides have. The life of the copper gauze on which the filtering material rests averages five or six years. It costs only a few pounds to replace, and the work of replacing can be executed very quickly by turning the filter on its side, fixing one half in at a time without removing the filtering material. The bottom and gauze can also be washed with a hose at any time and inspected without removing the filtering material.

The smaller sizes of the "turn-over" filter can be easily revolved for cleansing by hand. The power required for other sizes from 5 ft. up to the largest, 8 ft. by 21 ft., varies from 1 to 10 electrical horse power. Somewhat larger power must be allowed for if a gas or oil engine is used.

There is practically no loss of filtering material in the cleansing of the "turn-over" filter, because, unlike other filters in which the wash-water is being discharged at the same time as it is being allowed to flow into the filter chamber, the filter is specially arranged so that it is impossible to inject and eject the wash-water from the chamber at the same time. By this arrangement it is possible to place the discharge opening for the dirty wash-water close down to the surface of the bed, and, therefore, get rid of the dirt more thoroughly and rapidly by siphoning action.

For these reasons it is obvious that the cleansing and getting rid of the dirt is obtained with less expenditure of wash-water. It is also claimed that the cleansing of the bed is very much more thorough with the "turn-over" system than with others, and, above all, absolute uniformity of cleansing is secured.

It is easy to see that uniformity of cleansing is a great advantage, for if the bed is not uniformly cleansed when the filter is restarted the speed of filtration cannot be uniform on account of the portions which have received less cleansing offering greater resistance to the passage of water than those which are better cleansed.

The cleansing system in the "turn-over" filter is unique, and, seeing that the cleansing of a mechanical filter is the crucial feature, it is of primary importance, whether the filter is dealing with a comparatively good water, such as is met with for town supplies or dealing with a bad water, such as has to be dealt with, generally drawn from dirty rivers for use in industrial works.

Chemical Treatment.—As this paper has reference primarily to the design of filters, the design of chemical treating apparatus is not dealt with, but the following general remarks may prove of interest.

There are two systems of adding chemical solutions into the water to be treated, either by open nozzles by gravity or injection by means of small pumps under pressure. There can be no question as to the preference of these two systems, for the open nozzle system has very great advantages.

The advantage of allowing proper time for the chemical action and coagulation cannot be overrated. In dealing with river waters, which are always subject to turbidity, when there is no storage provided it is almost without exception more economical to provide for primary sedimentation and thereby relieve the filters of a large amount of the roughing work which can be done more cheaply by a few hours' sedimentation.

In such cases the open nozzle system of treating can easily be applied. There are, however, some waters, especially those highly peat stained, which may have been passed through a reservoir and by sedimentation the large suspended matter got rid of, the subsequent treatment of which requires a comparatively large amount of coagulant to get rid of the peat colour, where primary sedimentation, giving four to six hours, or even up to eight for coagulation and sedimentation, is in the author's opinion practically a *sine qua non*. The providing of sufficient time for the chemical action and sedimentation always means a saving of coagulant and a much more regular result, and where large amounts of coagulant are required, costing large sums annually, provision for proper time for chemical action and coagulation means a great source of economy.

The open nozzle system of treating is also much simpler and easier to regulate and keep in order and more accurate in proportioning the treatment. Wherever, therefore, this system can be applied it is an advantage.

Concluding Remarks.—In conclusion I wish to say that I shall be pleased to reply to any criticism on my remarks, and I wish to express my thanks to the Chemical Engineering Group for their assistance in enabling me to bring this paper before its members.

LIST OF VALVES, ETC.

Letter.	On Fig. No.	Description.
A	All Figs.	Wash-water inlet valve.
B	All	Wash-out valve.
C	All	Starting wash-out valve.
D	All	Inlet valve for raw water.
E	All	Outlet valve for filtered water.
H	Fig. 6	Air inlet from steam blower
J	Fig. 8	Sand washer.
K	Fig. 5	Injector for washed sand.
L	Fig. 8	Wash-water valve to jets in arms.

The CHAIRMAN said that every one of the members of the Society would read the paper, and read it with profit. The paper closed the meeting.

A NEW PROCESS OF CENTRIFUGAL FILTRATION.

BY W. J. GEE.

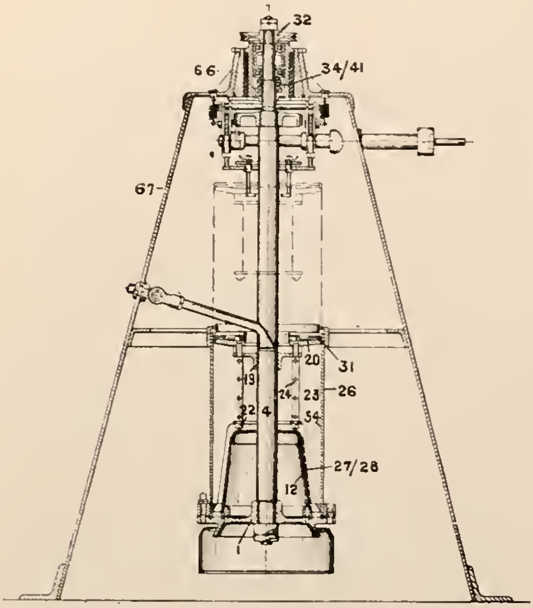
Centrifugal separators have long been used extensively in many industries. By far the most common type is the perforated basket machine, which is, in essence, a rotating sieve. The uses of this type in textile works, and laundries, and in sugar factories and refineries is so well known to chemical engineers that there is no need to do more than mention them.

Centrifugal machines having imperforate drums have also been used for certain purposes, and these must be regarded as, in essence, rotating settling tanks. The substitution of centrifugal force for gravity sedimentation results in a much quicker deposition of the suspended solids. In a special type of imperforate drum machine which, just before the war, I applied to the separation of china clay and like materials, the flow through the drum of the liquid carrying the suspended solids produced a graded deposit—the coarser and heavier particles near the inlet, and the finer and lighter near the outlet. The combination of separating and grading in the one operation was most interesting and of great practical utility in many cases.

The combination of centrifugal separation and filtration has been employed, the usual scheme being to line the perforated basket with filter cloth, and in cases where the suspended solids are readily permeable useful results are obtained. But when the solid particles are of a fine texture, the filter quickly chokes, and the effect thereafter is similar to that of an imperforate drum machine.

It is possible completely to remove suspended solids from a liquid, however fine the particles, in a solid drum machine by centrifugal force exerted over a sufficient time. But in many cases the last few grains per gallon of exceptionally fine particles require so much time that the output of the apparatus is severely limited. I have myself found that some 98 to 99% of the total solids could be recovered at a very high rate of feed to the machine, but to recover the other 1 or 2 the feed had to be reduced beyond what would be a commercially practicable limit. In one case, to obtain a perfectly clear effluent, I had to cut down the feed to one-thirtieth of the rate at which 98·5% was recovered.

Consequently, in cases where the liquid is required to be completely clarified, it was necessary to evolve some method of dealing with the finer particles with an efficiency more nearly approaching that at which the larger solids are dealt with by centrifugal force. The possibility of using a filter for this purpose, using the pressure derived from centrifugal force, was obvious, but a peripheral filter would readily choke, and bring one back speedily to imperforate drum conditions. Fortunately I had some prior experience which led me to consider the possibility of an exit flow under a centrifugal head, if I may use the expression, and I found in this a complete solution of the choking difficulty. The final form of the apparatus, which combines centrifugal separation with filtration through a non-choking filter, is illustrated in the accompanying sectional diagram. The drum (26) is secured to the base (1) by a bayonet-jointed locking-ring, the base being attached to a spindle (4) suspended from a patent ball-bearing. Rotation is imparted by the pulley (32). The bearing (34/41) is supported by a conical pedestal (67), to which is riveted a top casting of steel (66). The pulley (not shown) on the main driving shaft is fitted with a clutch of centrifugal friction type, which provides means for controlling the machine. The upper end of the drum (26) is closed by a top plate (20), which makes, during rotation, a watertight joint (31). This plate is provided with a central opening through which the machine is charged; it is also held centrally on the spindle by a distributing plate (19). Depending from tho top plate (20) is the container, consisting of six vertical rods (24), with attached vanes or blades (23). These extend the whole length of the drum, being connected to the top plate (20), middle plate (22), and bottom plate (25). They serve the double purpose of dividing the drum into six longitudinal compartments, and compelling the liquid under treatment to rotate with the drum, so avoiding slip.



Each compartment is provided with a thin residuum plate (54), forming a removable lining, curved to the radius of the drum. Upon these plates the recovered solids are deposited. When fully charged the container is lifted into the position shown in dotted lines. The recovered solids may then be removed without disturbance. A duplicate set of plates is supplied with each machine, and when the charged plates are removed the other set is inserted, and the machine put again into operation without delay. The charged plates are dealt with whilst the new charge is accumulating. Fitted to the base (1) is a perforated filter cone (12), projecting into the separator drum (26). A filter medium, cloth, paper, or other suitable substance, is wound round and secured to the outside of the lifting of the container in order to remove the filter cone by screwed wire clamps (27/28). The recovered solids is effected by a screw and bevel gear operated by cone clutches, connected to a continuously running counter-shaft, belt driven from the main power shaft. A nut carrying levers is connected by wire ropes to a ball-bearing turntable, provided with means of attachment to the top plate (20) of the container. This turntable allows the container, when lifted, to be easily rotated for access to the charge.

The first and most obvious advantage of this radical alteration in proportion is that the capacity of the machine in terms of recovered solids per charge is increased to from three to four times that of the hydro-extractor. But the difference between the two types goes deeper than this.

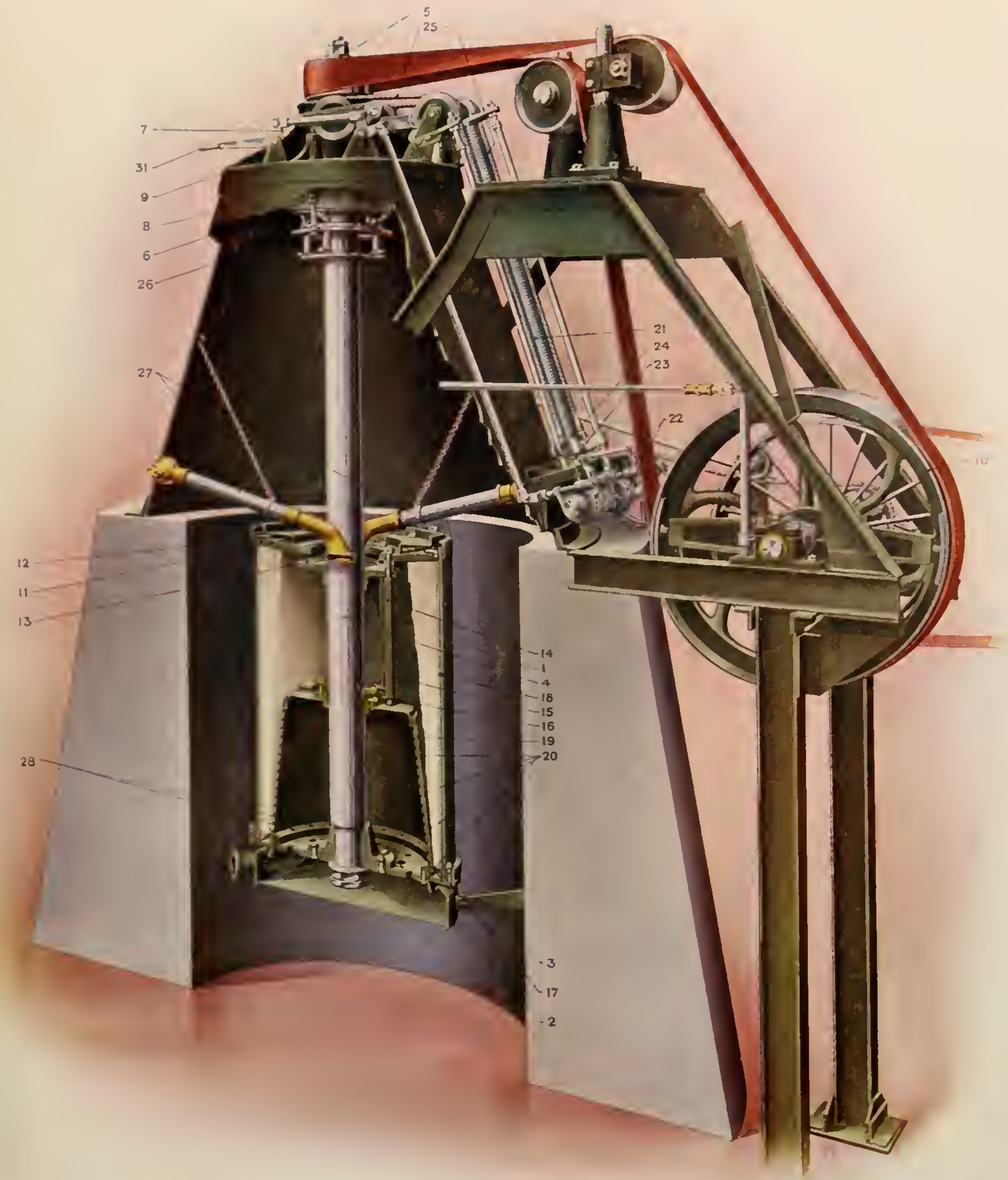
It is clear that the separating efficiency of a centrifuge depends, firstly, on the intensity of the centrifugal force that can be developed, and, secondly, on the quantity of material on which the centrifugal force is being exerted. In order to obtain the maximum centrifugal force, the diameter of the drum must be kept as small as possible. This is clear, since centrifugal force increases directly as the square of the number of revolutions per minute. The commonly accepted view that centrifugal force is proportional to peripheral velocity is incorrect. The earth has a peripheral velocity of about 1000 miles per hour, but it only makes one revolution per day, and so the centrifugal force generated is negligible.

Small centrifuges have been made, with drums of two inches in diameter, which have been run at such speeds as to give a centrifugal force equivalent to 70,000 times the force of gravity. But such machines have so small a capacity for retaining recovered solids, and the quantity of liquid on which the force is exerted at any one time is so little, that they have no commercial value.

The centrifugal separator is a compromise in which the antagonistic factors are reconciled to the best advantage. The drum is kept proportionately small in diameter, so as to secure the greatest centrifugal force, and it is lengthened in depth, so as to get the maximum efficiency in terms of the quantity of liquid constantly under treatment, and to obtain the maximum capacity of charge of recovered solids per run.

But this alteration in the hitherto accepted proportions entailed the consideration of new problems in the obtaining of perfect balance and in the damping out of the precessional oscillations which always attend high-speed rotation. To deal with these a new type of bearing was evolved, which is the subject-matter of a special patent, with the result that practically the only limit to the speed is the tensile strength of the drum.

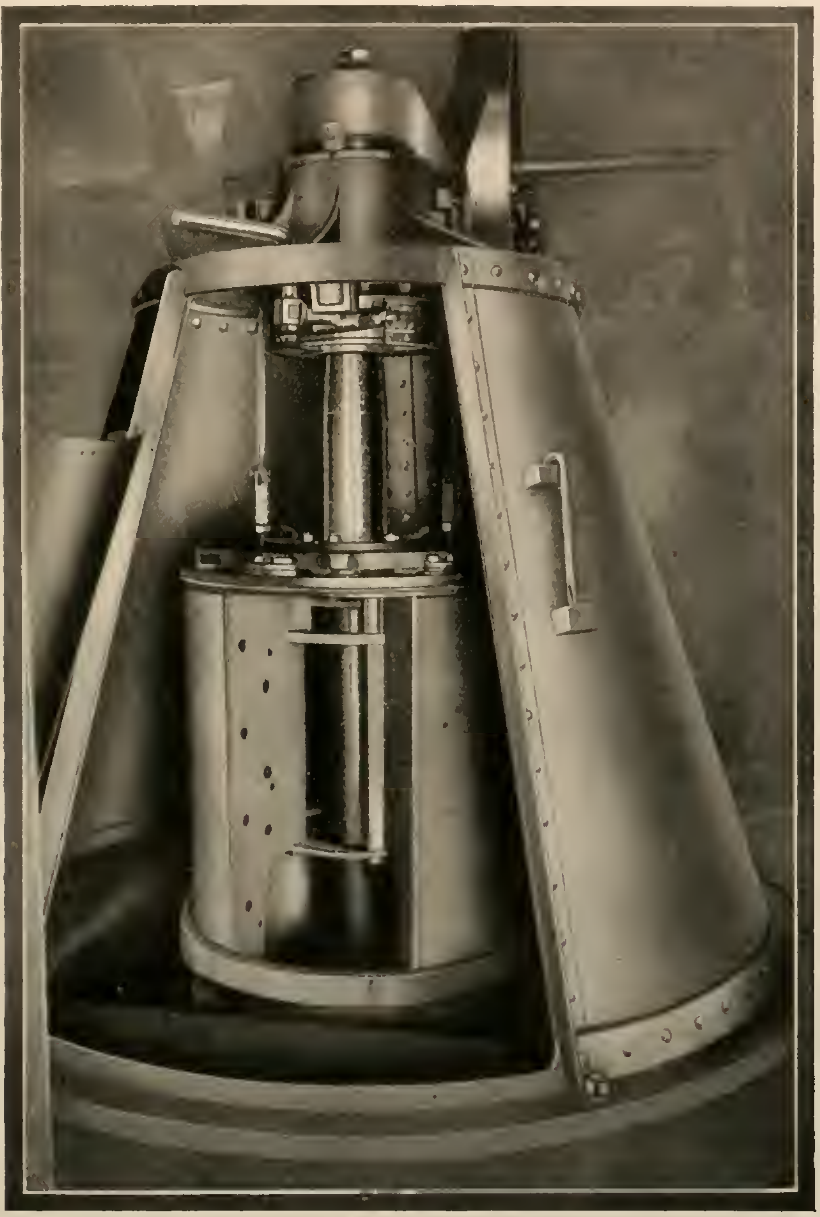
From a study of the foregoing it will be seen that the new type of centrifugal separator combines, in the one apparatus, a centrifugal separator, a grader, and a non-choking filter. It will be noticed that the proportions of the drum and the general arrangement of the machine differ considerably from usual types at present used, and an explanation of the principles which governed the design will be of interest.



36" GEE CENTRIFUGAL SEPARATOR COMPLETE WITH DRIVING GEAR.

I doubt whether any machines used in the chemical industries, excepting perhaps pumps, deal with as many varieties of materials under such different conditions, as filters, and so it will be impossible to lay down any rules that will be universally applicable. But as a general proposition, it can be stated with very great confidence that the new centrifugal filter has the following advantages over other filtering apparatus:—

1. The rate of filtration is constant throughout the charging period.



2. The filter, once made, is used over and over again; the removal of the recovered solids does not disturb it.

3. A very wide choice of filter material is available. Such materials as filter paper, asbestos, glass cloth, and so on can be used, as bursting of filter material is eliminated.

4. The removal of the recovered solids requires much less time than the cleaning of a filter press and the fitting of clean filter cloths.

5 The wear and tear of filter material is almost completely eliminated.

6. Materials which cannot at present be filtered at all commercially in filter presses, owing to choking, can be dealt with in the centrifugal apparatus without difficulty.

7. The apparatus lends itself to heating or cooling, so that materials may be treated at any required temperature.

8. The rotor can be readily enclosed completely for the filtration of volatile or dangerous liquids, which may be treated at any pressure or temperature. In recovering suspended solids from volatile solvents, loss of solvent and danger of fire or explosion are eliminated by using a totally enclosed machine.

9. The recovered solids are graded as to fineness

of particle in a very exact manner, which is unvarying on repetition, so that standard qualities of materials are assured.

It will be readily understood that the machines, especially in the large size, which is capable of recovering upwards of half a ton of solids per charge, need to be made with the greatest exactitude so that the rotating drum is in perfect balance, and only the finest materials may be used. My company has been fortunate in arranging for the manufacture of the machines by Vickers, Limited, at their Barrow works, and, if I may say so with due modesty, I would claim that the machines now being turned out by that firm not only reflect great credit on them, but also far outstrip anything that has yet been done in this or any other country. The rotating weight is very much greater than has hitherto been thought possible, and the speed of rotation is much higher. The machine runs with perfect steadiness, and, once the conditions necessary for perfect result with any given material have been ascertained by trial runs, it requires a minimum of attention, and the upkeep costs are practically nil.

In conclusion, I would like to mention that there is an experimental and research works in London, where machines are constantly running, and it would give me great pleasure to have a visit there from any member of the Society who would like to see the filter working.

Discussion.

Mr. **Foster Sproxton** said the chief criticism one heard of the Gee Centrifugal Separator was that if they were dealing with a liquid containing a considerable amount of solid material in suspension, that the stoppages of the machine for the purpose of clearing the residuum plates were somewhat numerous, and the labour cost therefore came rather high. It had occurred to him that if one were dealing with something of that kind, providing the grading itself was not necessary, it would be an economical proposition to combine the Sturgeon Separator, described the previous afternoon, with the Gee described that morning, so that one might pass the liquid first of all rapidly through the Sturgeon, and reduce the amount of solids by about 90%, getting automatic discharge of the bulk of the solids in that way, and then pass the effluent through the Gee separator, and obtain the removal of the whole of the remainder of the solids. Possibly the criticism as to the high cost of labour Mr. Gee was prepared to meet, but it occurred to him that was a suggestion which might possibly be useful.

Dr. **W. S. Jerdan** asked if it was possible to obtain a perfectly clear filtrate from liquors such as glue liquors, in which many of those present were interested.

Mr. **E. Holmes** asked if the machine was running quicker they would be able to get a greater out-put and less grading.

Dr. **Thorne** asked Mr. Gee if he had had any experience with this machine in the filtration of difficult filtering materials such as raw sugar stuff. It seemed to him that the apparatus, with the grading it gave, might help very materially in that respect.

Captain **C. J. Goodwin** asked what was the reason of the cone at the top of the machine which appeared to enclose three-quarters of the shaft and left only about one quarter of the machine exposed for the removal of the plates. It seemed to him that time might be saved if the whole of the top of the machine was exposed, and instead of having only two men to take away one plate at a time, they could take away the whole at once. He would also like to ask whether the handling of these plates could not be simplified a little. It seemed to him it was very essential in all these machines to increase the out-put as much as possible, and to minimise the time not usefully employed in filtration.

Mr. **W. Ramsay Sibbald** said that one of the most difficult problems in filtration was that of filtering crude oil, such as crude cotton seed oil. The material to be removed was of a very sticky nature, probably not very much higher in density than the surrounding liquid, and the liquor itself was viscous. Probably Mr. Gee could tell them something out of his experience. He would also like to know how completely the liquid could be discharged after the solids were removed.

Mr. **J. Arthur Reavell** asked whether Mr. Gee had constructed the machine so that the whole of the plates coming into contact with the liquor were made of gun metal or of copper so that they could tackle such liquors as gelatines, which would want copper contact.

Mr. **N. C. Neill** said the thing that struck him, looking at the picture, was that parts of the cake were apt to drop off. He had noticed the same at Felling, where he had had the opportunity of seeing the machine at work. He would like to know if Mr. Gee had now modified the machine so that it was easy to get inside the machine to clean it out. If they had more or less a cwt. of solid inside the machine it might take the best part of an hour to get it out.

Mr. **F. R. O'Shaughnessy** said one was interested in the proportion of water still remaining in the solid. What, approximately, might be the percentage of water in such solids?

Mr. **H. Finnemore** asked the author if the machine was made for smaller batches than the one he had just shown—a cwt. or so.

Mr. **N. P. Wilson** asked if the construction of the machine was such that it would deal with solids that were of slightly lower specific gravity than the liquid in which it was suspended.

Mr. **A. E. Malpas** said he did not think any previous speaker had given Mr. Gee credit for what his claim was. That was that the machine did something no other separator would do, and that was to grade the product. Mr. Gee was after a definite thing, and he appeared to have got it.

Mr. **R. A. Sturgeon**, called upon by the Chairman, said he had nothing ready which would interest the meeting. The only thing he could say was that he considered the Gee machine was a very fine piece of work, and that it had its place in the scheme of centrifugal machinery in general, and that it should be a most valuable help to the chemical industry. It had, of course, the disadvantage of not being a continuous running machine, but, on the other hand, it had special features which were not possessed by any other centrifugal machines. For machines which had to be stopped in order to extract the solids it probably had advantages over any other of that class of machine. It was probably the last word in that class of machine for separating fine solids from liquids.

Mr. **Jas. MacGregor** said he was very interested in the separation where the affluent was of no consideration, but what application had the machine to a mixture where the object was to recover the liquor, and where it was highly desirable to wash the solids on the plates. Had Mr. Gee given any consideration to the question of washing the cake?

Mr. **A. J. Broughall** asked whether any experiments had been made with this machine in removing some substance from a thing which, by the application of heat, could be melted.

Dr. **L. F. Goodwin** said he was very anxious to get some information on a really efficient centrifugal filter of the type described, but his difficulty that day was the same as it was the previous day—he would like to get some precise figures as to what the machine would do. Mr. Gee stated in one of the pamphlets that with a liquor containing 10 of solids they could discharge the drum about four times per hour. Many besides himself would find it an advantage, he thought, if they had some sort of formula to work on. If he had a liquid of 20 of solids, would he have to feed in half the quantity, and would he be able to discharge the drum, say, eight times an hour instead of four times an hour? That would be a guide. And then his other difficulty was, supposing he increased the percentage of solids, say, 30, 40 to 50, would Mr. Gee recommend the machine in preference to a filter press of the Sweetland-Kelly type? Where would he draw the line? Where would the machine cease to be economical?

Mr. G. Gunn asked Mr. Gee if he could give him some idea as to how the machine would deal with paper mill effluent containing fibre not more than three millimetres in length, and specific gravity of 1·5, China clay with a specific gravity of 2·5, starch and a quantity of resin. This paper mill effluent was extremely valuable, and the machine that could get them out all mixed up together would be of great value.

Mr. Alan Rhead said he thought the question of action of acid on the machine and the erosion on the rotating parts should be gone into very deeply.

Mr. Gee, in reply, said he thought it would be agreed that he was right in saying that the discussion was almost the most interesting part of such a paper. They had had quite a number of points raised that he would have found it difficult to bring in in the course of a few introductory remarks. Mr. Sproxton had mentioned that he considered the stoppages of the drum for the removal of the solids were frequent and would retard the operation. After all, one had to consider the efficiency of such a machine, either in terms of the amount of solids recovered per hour or per run, or one had to consider the efficiency in the quantity of liquid clarified, in cases where there was only a tiny proportion of solids, and where they used a filter press or other method, the greater the amount of solids there were the greater the amount of labour that must be expended to get rid of them. What they ought to consider in this case was that by taking out the solids on plates they not only got the advantage that their deposit was undisturbed, but they had also got a much more efficient system of handling the recovered solids than the ordinary way of scooping them out. If the machine was rotated at a higher speed, of course, the centrifugal force increased. The higher the speed the greater the yield, but, after all, there was a limit to the strength of metals, and although the speed may be increased somewhat, he would not like to be responsible for increasing it unduly. The grading would not be affected by increasing the speed, but the position of the particles in the drum would be varied. Then there was the question of sugar filtering. As it happened, for the last six or eight weeks he had been in Madeira testing the working on sugar, and he was glad to say the results obtained were extremely satisfactory. They found that they could get a perfectly clear filtrate from the juices, but when they came to deal with raw juices, there were among the suspended particles a certain proportion which were lighter than the juices, and they tended to stay on the cone. But after carbonatation these lighter particles were reduced in number, so that the machine worked perfectly clearly, and gave a perfectly clear effluent. Captain Goodwin raised the question of the reason of the cone frame. Unfortunately the machine could not hang in the air. It must have something to rest upon, and they would notice that the whole of the weight, and it was very big, was suspended from one bar, and the object of the cone was to anchor and to give it the most rigid support possible. Although the opening in the cone might be made larger, there was not much point in it, because the container could be moved round. It was really quicker to move the container to the operator than that the operator should move round to the container. Mr. Sibbald was discussing the filtration of cotton seed oil, and that would apply to similar substances which were very viscous. They had been doing a good deal of experimental work in the matter of oil filtration, and they had found that provided the liquid could be heated to such an extent that the viscosity was reduced, they could get a very good filtration indeed at quite a good rate. Then there was the question of machines made of acid resisting metals. There was no difficulty about that. There was also a proposal for lining the rotating drums and covering the working parts with hard rubber which in many cases might be perhaps preferable. Mr. Neill raised the question of the solids dropping off the drum. That was a difficulty, but a slight modification in the shape of the ends of the plates had had the effect of reducing that, so that now it scarcely ever happened, if at all. They had been asked about a small machine. There were two sizes made at the present moment, a 36 in. diameter and a 12 in. diameter, the 12 in. having a capacity of about one-tenth of the large one. Mr. Wilson raised the question about solids lighter than liquids. The fact was that the solids went to the interior, and were deposited on the filter pole and did not throw off until the liquid receded. In the course of his work at Madeira he had found a rather interesting point about these carbonate juices. He first of all started a machine by using a fairly thick and dense filter because it was obviously necessary to get the juices as clear as possible. Well, the rate of flow through the machine with a dense filter like that was somewhat slow, and the result was a large proportion of the suspended particles separated by centrifugal force, and the filter only retained the lighter particles. This did tend to choke the filter and reduce the efficiency somewhat. Then he put on a filter which was rather less dense, but still gave him the necessary clear filtrate, and that enabled him to run the material through the machine faster with the result that the filtrate cone retained not only the solids lighter than the liquid, but also some of the finer parts of the heavier than liquid solids. When he attained those conditions it went on without choking at all and gave good results. It was rather a practical proof of the action they claimed for the filter that it did automatically throw off the solids and kept the thing clean. He wanted to thank Mr. Malpas for his very complimentary remarks on the grading effect of the machine. He did not deal with it particularly in his opening remarks because it was fairly well described in the paper. In many cases it was a very important function of the separator. Then there was the question of Mr. MacGregor about the washing of the filtrate cake. The washing of solids in filtering apparatus was a very important and somewhat difficult question. In ordinary filter presses wash water might be pumped through after the cake of solids had been obtained, but there was a tendency for water to find easy channels through the cake and make the washing local. Special filter presses had been designed which provided for steeping the solids which was probably about the best available way of getting a thorough wash. They were carrying out now tests for producing substantially the same washing effect in the separator. He thought they would shortly be able to announce that they had a very efficient washing system. Dr. Goodwin wanted figures. Well, so did he.

But they were only just now getting this machine into the various works, and they were collecting the figures as quickly as they could. As soon as they had them they would be only too delighted to give them. Such figures as they had obained were freely at the disposal of those present. Specifically Dr. Goodwin asked whether supposing one had 10% solids in the liquid and were able to discharge the drum four times an hour, could one get 20% of solids discharged eight times per hour. One could not, because they would cut in half the time taken by feeding in the charge. The stoppages and starting would take more time, so they would get more, but not twice the amount. About the paper mill effluent. They had tested paper mill effluent, and they obtained satisfactory results with it, and indeed, machines were on order for that purpose. On the question of exact figures he had a letter which had been sent on to him that morning describing the working of a machine which had just commenced work at the factory of the National Dyes, Ltd., near Manchester. This letter stated that they were able to get up to 2 cwt. in ten minutes as compared with 12 hours in the filter press, and they felt sure they would be able to get better results later on. That machine was working on dyestuffs, and evidently on the same material which was extremely difficult to filter in the ordinary way by filter presses, but, as they said, in the Gee machine that material threw off and no choking took place. That was the 36in. machine. One other point he would like to refer to in connection with special machines for special purposes. There was also the condition that sometimes machines had to run with material that had to be heated, and sometimes material that had to be cooled. In other cases machines had to be totally enclosed. All these things could be done perfectly simply by taking special metals to make the machines of or in the case of heating or cooling, to provide coils round the rotating drum, and the machine could be completely enclosed to work under pressure. All he need do now was to repeat the invitation he gave, and say that if any member of the Society would like to go to their demonstration works in Peckham, it would be a pleasure to receive them.

The CHAIRMAN, moving a vote of thanks to Mr. Gee for his paper, said he understood their colleague was the inventor of the machine, and he would therefore move a resolution of congratulation on his invention.

THE PRINCIPLES OF TECHNICAL FILTRATION.

BY EMIL HATSCHEK, F.INST.P., A.M.I.MECH.E.

(*Abstract.*)

Filtration is generally defined as the separation of liquids from solid particles of microscopic size suspended in them, by means of a porous septum which allows the liquid to pass but retains the particles. The definition is somewhat narrow, as, on the one hand, it has been shown by the author[1] that particles of one liquid suspended in another can be retained by suitable media, while, on the other, colloidal particles of sub- and even amicroscopic size can be separated by a variety of membranes. The procedure last mentioned is known as "ultra-filtration," and, while it is an important instrument of research, has not so far found application on an industrial scale; such application, however, should be quite feasible, a point which will be referred to again.

As regards filtration in the narrower sense, the mechanism of the process has been fully discussed by the author in a paper under that title.[2] Much of what follows is therefore recapitulation, which, however, the author's technical experience has shown him to be by no means unnecessary.

The first and fundamental point to be noted is that, for a given system of solid and liquid, the whole problem is completely determined physically. The size of the pores in the septum is fixed or has, at any rate, an upper limit; the largest number of pores of such size is, of course, desirable, but this is a technical matter and simply means a choice among a comparatively small range of materials. As soon as filtration begins the pores in the surface of the filtering medium are throttled more or less by the particles which settle on them, and as it proceeds the liquid has to escape through these throttled orifices and through a layer of particles of increasing thickness. The structure of this layer is also fixed by the size and shape of the particles, and is, for a given precipitate, remarkably constant. The resistance offered to the flow of liquid varies considerably from one material to another, but in all cases it increases as the thickness increases, until a limit is reached, *i.e.*, until, with a given pressure the rate of flow becomes so small that it is advisable to discontinue the process. This limit is an *economical* one only; it depends, roughly speaking, on the way in which higher pressure increases the first cost of the plant, and, the pressure being given, on the balance between the cost of obtaining a thicker "cake" and the cost of removing it at more frequent intervals. The proper adjustment of these factors presents no difficulty to anyone experienced in designing filtering apparatus, and should be left to him.

The second point is that since the structure of the cake is fixed by the size and shape of the particles, not only the pressure required to force through a given thickness of it, but also the percentage of mother liquid remaining in it at the end of the operation is fixed within surprisingly narrow limits. It is not affected by the design of the apparatus nor by the pressure used—a point which seems self-evident. No experience is more common than to be asked to design a filter which will turn out a cake containing "not more than 20% of mother liquor," the cake being, *e.g.*, calcium sulphate, which contains about 40%. This figure is the same whether filtration has taken place in filter presses or on vacuum filters, through filter cloths or through porous tiles. Only actual experiment can, in the case of an unknown residue, give any information regarding the amount of liquid retained by it. It is hardly necessary to say that the appearance and consistency of the cake are no guides; an excellent "cake," say, of calcium carbonate may turn to a fairly fluid sludge during carting, owing to a slight rearrangement of the particles. In cases where the particles are not solid crystals, but themselves aggregates, the moisture content may be remarkable while the cake can still be handled perfectly. Thus a cake of the "magnesium carbonate" used as non-conducting covering retains about 75% of mother liquor, owing to the very peculiar structure of the material.[2] The author once showed a specimen of this cake to a client used to China clay, who guessed the percentage of moisture as 25%, or thereabouts.

The case appears even more complicated when the residue is highly hydrated, *e.g.*, amorphous silicic acid. In this case the residue contains not only the mother liquor between the particles, but the water of hydration in the latter, all, or nearly all, of which would be driven off on drying at 100° C. The only way to determine in such a case the percentage of mother liquor, as distinct from water generally, is to titrate whatever constituent of the mother liquor is most characteristic.

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[1] E. Hatschek, "The direct separation of emulsions by filtration and ultra-filtration." J., 1910, 125; E. Hatschek, "The mechanism of filtration." J., 1908, 538.

[2] *loc. cit.* Fig. 27.

In a great number of processes it is necessary to remove the mother liquor as completely as possible, either because it contains the valuable constituent or because its presence in the cake is detrimental. The most common method is to displace it by water (or other solvent), *i.e.*, by "washing" the cake, as it is usually called. The ideal—displacing the mother liquor by an equal volume of water or solvent—is practically unattainable, as a certain amount of diffusion is unavoidable, but where this is slow the volume of wash-water may be very little in excess of the volume of mother liquor to be displaced. The process of washing resembles the process of filtration, with two important differences: the liquid passes through a constant, instead of a gradually increasing, thickness of residue, and the process, unlike filtration itself, is not self-regulating. To illustrate this point, we may take the case of a suspension being filtered through a material, the porosity of which varies slightly at different portions of the surface. The liquid passes more rapidly through the more porous portions, and a correspondingly larger amount of solid is deposited in a given time, which checks the flow and tends to equalise it with that through the less porous parts. If wash water is now passed through, the difference in porosity, although greatly reduced by the layer of deposit, will still cause the flow of wash water to be more rapid at some spots than at others, and this inequality no longer can correct itself, so that washing is uneven. Differences in the structure of the cake, due to other causes, will have the same effect.

The point to which washing is carried is again settled by economic considerations—such as the balance between the cost of evaporation and the value of the dissolved substance—unless, for instance, traces of the mother liquor are absolutely detrimental to the purpose for which the residue on the filter is required. If this is the case, the end point is by no means easy to determine; generally speaking, it is not sufficient to test the washings only, but the cake itself should be examined. Apart from very exceptional cases, adsorption always occurs on the particles of the cake, and although the washings show no reaction, a thin layer of adsorbed solute is nevertheless present, which may be discovered by testing the cake itself. As the latter is dried, the concentration of the adsorbed solute increases and may attain quite objectionable proportions even when washing has been carried so far that the last washings show no reaction. The case is aggravated when the particles of cake are themselves porous, *e.g.*, materials produced by fusion with alkali or the like. In these cases the wash water may quite rapidly displace the mother liquor between the particles, but the liquor in the pores of the particles can escape only by diffusion, which is necessarily slow. When these conditions prevail, even the cake may appear neutral after prolonged washing, but shows marked alkaline reaction again after standing for some time, during which diffusion out of the particles into the water between them occurs. It is therefore quite useless to hasten washing, and the sound procedure is to make it so slow that it proceeds *pari passu* with diffusion. This, again, is a state of things which cannot be altered by the design of the apparatus or by increasing the working pressure, but must be accepted as following inevitably from the nature of the material treated.

Both during filtration and during washing it is necessary to maintain a difference of pressure between the two sides of the septum. How great this is to be and how it is produced are technical and economical problems. The function connecting the rate of flow through unit area of a given material with the difference of pressure is not known, and it must obviously be complicated in the technical case, *i.e.*, a layer of increasing thickness building up on a porous surface which remains constant. Even for a porous material alone, or for such a material covered by a definite layer of particles, the function is certainly not linear, or, in other words, Poiseuille's law does not hold. It has been quite frequently assumed that it does, but even *a priori* there appears to be no reason why it should, since the pores in the filtering materials used technically are quite certainly not cylindrical. In the few cases investigated by the author[3] the curve plotted with rates of flow as ordinates against pressures as abscissæ shows an inflexion and then approaches a parabolic type.

As the pressure is applied to or through the liquid in which the particles are suspended, the latter are in no sense pressed together, but are simply left behind as the corresponding quantity of liquid escapes through the septum. It therefore follows that the structure of the cake and its content of mother liquor are not affected by the pressure employed—a point on which the most common and serious misconceptions exist. It need hardly be said that this statement does not apply to centrifugal filters, in which the structure of the cake also depends almost entirely on the shape of the particles, but in which acceleration is imparted to the liquid, so that—in ideal cases—the whole of it may be removed.

If a difference in pressure of about 14 lb. per sq. in. is sufficient, it may, of course, be produced by maintaining a vacuum on one side of the septum, while the liquid to be filtered is exposed to atmospheric pressure on the other. The case does not differ theoretically from any other, but the technical differences between it and filtration under pressure (in the technical meaning) are so great as to justify separate treatment. The most striking feature of the vacuum filter, as this type is called, is the accessibility of the cake during and after its formation. Apart from the facility of removal, this is of advantage in permitting the correction of defects in the uniformity of the layer, which render washing imperfect. On the other hand, vacuum filters cannot be used for liquors having a high vapour pressure at the time of filtration (*i.e.* volatile or hot) unless a condenser is provided. The liquid from the filter must be delivered into a closed receiver—which may, of course, be structurally in one piece with the filter itself—exposed to the external pressure of the atmosphere. The ordinary Buchner funnel and filter bottle together form a model of this type.

The accessibility of the cake makes possible the design of the various types of "continuous" filters, into which, as into other purely technical details, it is not proposed to enter here. Another very interesting possibility remains so far unexplored, *viz.*, the combined use of filtration and decantation. Many of the more common precipitates settle fairly rapidly, either because the particles, although of low specific gravity, are large—*e.g.*, calcium sulphate or calcium carbonate as arragonite (*i.e.*, precipitated from hot solutions), or because the specific gravity is high, as with barium or lead compounds—over 6 in the case of the chromates or sulphate of the latter. To take a fair numerical example, we may assume a rate of settlement of 1 cm. per minute. If this suspension is now fed at one end of a long vacuum filter at such a rate that it will take, say, 1 min. to reach the opposite end, there will be a depth of 1 cm. of clear liquid from the surface, which can be continuously drawn off over a suitable weir, provided, of course, that the rate of feed is sufficient. Calculation can only be quite approximate, as liquid escapes already through the filtering medium on the way to the weir, and as, furthermore, the velocity of settlement is affected by the horizontal flow across the filter and the vertical flow towards the filtering surface. Experiment would be quite easy, and the method seems to deserve trial in many cases, especially where the solid matter is coarse or heavy and the liquid itself runs to waste, so that a very slight turbidity would be of no consequence.

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[3] *loc. cit.* Figs. 13 and 14.

It is obvious from the foregoing that the process of filtration is quite independent of the nature of the filtering material employed. The conditions the filtering material has to fulfil are three: it must have pores of the required size and as numerous as possible, it must be of sufficient strength mechanically to stand the pressure applied, suitable methods of support being assumed, finally, it must be chemically indifferent to the liquids to be filtered. As regards the first two requirements textile materials have very considerable advantages and especially the slight thickness sufficient to bear considerable tensile strains makes possible the design of apparatus, such as filter presses, possessing a large filtering surface in a small space. As regards the third one they are less satisfactory and the use particularly of woollen filter cloths (for acid liquors) is becoming economically impossible. These cases can be dealt with by the use of porous tiles or plates either consisting of silica or materials of high silica content or of carbon. The latter material is ideal as it resists both acids and alkalis; it is, of course, understood that the material consists entirely of carbon and not merely of carbon particles agglomerated by a silicious binding agent. Such porous plates, made by carbonising at high temperature a mixture of ground coke and tar, have been made in Germany for a considerable time, but their manufacture has not so far been taken up in England or the United States. This material enabled the author to solve a problem which, if not important or of frequent occurrence, is certainly interesting, viz., the filtration of hydrofluoric acid. A vacuum filter of antimonial lead with carbon plates as filtering medium was used and it seems doubtful whether any other combination could have answered the purpose.

A drawback of such porous plates is their thickness, which is called for more by reasons of manufacture and transport than by the conditions of use, as (apart from the difficulties of using suitable materials of construction) it is next to impossible to devise apparatus of the filter press type. The filtering surface to be obtained with a given volume and weight of apparatus is therefore necessarily smaller than in filter presses. In cases where a small amount only of solid material, which can be run to waste, has to be removed ceramic materials offer an interesting possibility, viz., the use of hollow cylinders, *i.e.*, "filtering candles" of large size. A large number of these can be assembled in a small space, the residue being removed by reverse flow and subsequent rinsing and flushing. The author has designed such filters for corrosive liquors having a filtering surface of about 105 sq. ft. in a volume of about 22 cub. ft., a ratio comparing favourably with that of filter presses (which would have been inapplicable). At present such porous cylinders are not manufactured in this country, but there appears to be no reason why they should not be.

A third type of filtering material remains to be mentioned which so far has found application only in research and on the laboratory scale, but appears to be capable of much more extended use. This comprises the membranes generally described as "ultra-filters" which are capable of holding back particles of submicroscopic size. Those used in the laboratory are prepared by impregnating filter paper with collodion (*i.e.*, solutions of nitro-cellulose in ether-alcohol or in glacial acetic acid) and gelatinising the latter by immersion in water. This removes the solvent and leaves behind a gel of nitrocellulose the permeability of which can be regulated within wide limits by choosing the concentration and controlling the removal of the solvent. There seems to be no reason why textiles should not be treated in the same way as paper, in which case the membranes could be employed in apparatus of the filter press type. They have to be protected from drying, but this is not difficult and such filters could probably take the place of pulp and similar filters where very brilliant filtrates are required.

All that has been said so far seems very simple and can be discovered by the aid of commonsense and a very elementary knowledge of physics. While it will not enable every reader to design filtering plant himself the author hopes that it may make him realise what information he has to give to people qualified to do so when he wants them to meet his requirements. This would appear to be an easy matter, but in an experience of about fifteen years the author hardly remembers as many inquiries which were approximately complete. There is, of course, in the first instance, the general reluctance of chemical manufacturers to give any details at all coupled with the conviction that any appartus to be worth considering should have treated exactly the same material, and that this "must be seen to be believed." There is also a genuine ignorance of the essential factors but for which such inquiries as the following would be impossible: "We want to filter five tons per day of a precipitate something like barium sulphate" (volume of liquid not mentioned), or "We require a filter for a difficult residue which is not to contain more than 10% of moisture" (nature of residue not stated, but discovered, on tactful cross-examination, to be one which normally retains 25%). This ignorance is not surprising when it is considered that the filtering appliances and methods which the chemist begins to use at a very early stage of his career differ widely from those used on the technical scale, and that his attention is never directed to the economical factors which determine their design, such as rate of filtration, amount of wash water, limits of washing, etc. The author does not propose to enter into the vexed question what amount of training in chemical engineering is desirable or necessary to remedy this and similar lacunæ in the education of chemists, the less so, as in the present case there is no difficulty in using small apparatus designed on the lines, and made of the materials employed on the large scale, and more particularly of filters for use under pressures of several atmospheres. The author knows of several institutions in which such apparatus is used regularly for preparative work with quite decided benefit to the students and its use ought to be general.

Discussion.

Professor J. W. Hinchley (London) said he was interested in this matter because it followed Mr. Hatschek's very valuable paper which he read before the Society of Chemical Industry, London Section, in 1908. If they would read that paper of 1908 carefully they would find they would get a great deal of valuable information, but unfortunately they might get a misconception if they were not careful. Although they were discussing Mr. Hatschek's present paper he wanted to refer to something which was said in the former paper because it had a great bearing on the present one. Perhaps it would be easier to read the paragraph in the present paper. It was: "As the pressure is applied to or through the liquid in which the particles are suspended, the latter are in no sense pressed together, but are simply left behind as the corresponding quantity of liquid escapes through the septum. It therefore follows that the structure of the cake and its content of mother liquor are not affected by the pressure employed—a point on which the most common and serious misconceptions exist." In the paper of 1908 a series of experiments were described, showing that at whatever pressure a material was filtered, the composition of the cake was hardly affected. The general conclusion that would be drawn by the reader that the resistance to flow through that cake was not affected was not stated, and he might say was not true, because it was obvious that they could pack particles in the same space, and yet the resistance to flow of the liquid might be very different. If they took the particular direction in which they packed cylinders they got an enormous difference. He suggested that Mr. Hatschek was rather at variance with practical experience in this matter, and if there was no pressure on the particles, if the particles did not sustain any pressure when in contact with the septum, one reached a point in which one could not understand really what happened. As a matter of fact, in a pressure filter there was no pressure at one side of the septum, and there was maximum pressure on the cake. On the other hand, those who had carried out experiments would know if they filtered under one pressure they would find, if they washed, a precipitate which was filtered at, say, 10lb. a square inch, and they washed it at a range of pressure, they would find the rate of washing was about proportional to the pressure. If they filtered at a higher pressure, again the rate of washing would be somewhat proportionate to pressure. At very high pressures of washing, with low pressures of filtration, the cake might break down. It seemed to him that that was in keeping with what one would expect. The structure of the cake was far more porous with low pressures, and so most practical men who had to filter did not usually filter at a low pressure and wash at a high pressure. He suggested, therefore, that this misconception which was referred to was not quite true, and that Mr. Hatschek had not expressed himself quite clearly as to what he meant. Professor Hinchley said he would be glad to know, in continuance of the paper, exactly what was meant by that paragraph.

Replying to a question, Professor Hinchley said the rate of washing was faster if they filtered at a low pressure than if they filtered at a high pressure.

Mr. R. C. Campbell said it was his experience that with a plate frame filter, where they could press between two solid frames, they could get a more complete cake.

Mr. F. R. O'Shaughnessy said that one often came across cases where filtration was really the separation of all the visible suspended matter. He suggested filtration was the separation of all visible particles.

Dr. W. R. Ormandy said it did not seem to him advisable that the term should be limited. There were many other things in the paper of Mr. Hatschek. He referred to the possibility of filtration of what were called ultra-microscopic particles by the possible use of a septum made of nitrocellulose. Surely it was as much filtration to take out any particle which was capable of being distinguished from the liquid in which it was suspended by any of the ordinarily known means. If they could discover particles by the ultra-microscope and get a result, surely that fell under the heading of filtration, or, if they liked to use the term, ultra-filtration.

RECESSED PLATE AND PLATE AND FRAME FILTER PRESSES: THEIR CONSTRUCTION AND USE.

BY EUSTACE A. ALLIOTT B.SC.(ENG.), A.M.I.MECH.E.

Although much has been said and written about the filter-press, little has been mentioned concerning working conditions and performances. The object of the present paper is to make clear the construction and meaning of the numerous variations of type for those who have not had time to give special study to the matter, and an endeavour will be made to give helpful data and suggestions as to the use of this type of plant. In order that the various particulars may be as up-to-date as possible, a special effort has been made to obtain recent data from users which will represent their normal works practice. The figures given, therefore, are not test figures taken on a small scale, but may be assumed to apply to every-day large-scale operations. It should be understood, however, that the same material may vary widely in its filtering qualities, these differences being sometimes due to almost imperceptible variations in manufacturing processes, and in considering any particular problem due weight must be given to this point.

It is proposed to deal with the subject in the following order:—

(1) Construction of the simple or "non-washing" filter press.

(2) Choice and care of the filter cloth.

(3) Theoretical and practical considerations concerning pressure, viscosity, rate of flow, cake thickness, size and shape of suspended particles, etc.

(4) Methods of feeding the press.

(5) Washing in the filter press, with details of construction, theoretical and practical considerations and results.

(6) Air drying, steaming, hot and cold presses, etc.

(7) Labour in discharging.

Owing to the familiarity of the filter-press it does not usually receive the attention it deserves, which would doubtless be accorded to it if it were a new piece of apparatus, or if the simplicity of its operation were less obvious. Nevertheless, even with such an apparently simple piece of plant, the application of a little intelligence and understanding will bring increased satisfaction, both in the choice of the press itself and in working it with minimum labour costs, maximum output, and best extraction of soluble matter from the cake.

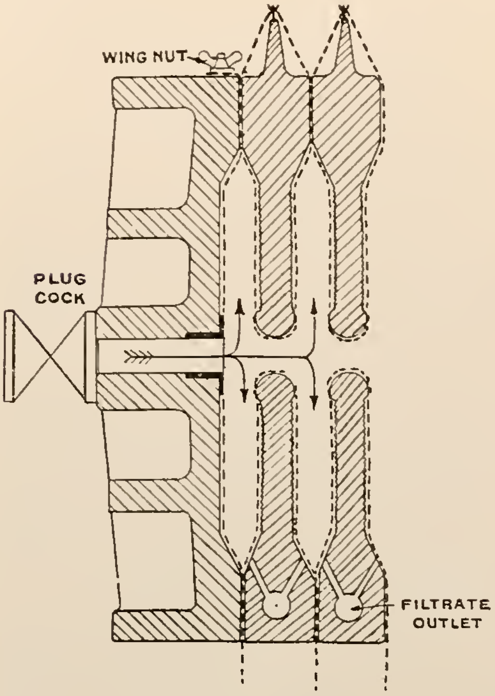
Construction of the filter-press.

A filter-press may be described as a frame in which a number of loose slabs of filter surface may be clamped to form a series of hollow chambers capable of withstanding internal pressure. The filter surface is ribbed or grooved and covered with cloth. This arrangement gives a maximum of area in a minimum of space, and is capable of modification to meet the varying conditions called for by different grades of material, both as regards thickness of cake, suitable pressure, varying filter media and arrangements for washing and steaming the cake when formed. A large variety of constructional materials can be used, and the whole plant is of high reliability and free from tendency to break down.

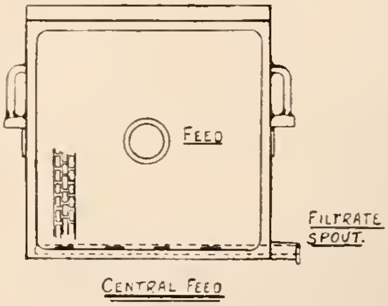
Two forms of press are in general use, namely, the recessed plate type, and the plate and frame type. These are often referred to as chamber presses and frame presses respectively. In the former type (Fig. 1) the rims are raised, so that when two plates are brought together edge to edge a hollow chamber is formed between them. The feed passage is taken through the body of the plate, while the filter cloths are laid over each side of the plate, forming a pressure-tight joint at the rims when clamped up, and having holes for the feed passage, which are sewn together or clipped to make a joint at the corresponding hole in the plate. This type of press has the merit of being the least expensive and requiring less labour. It is very suitable for thin cakes, owing to the free communication of the feed passage with the chambers. The usual cake thicknesses are 1 in. on the smaller sizes, 1½ in. on the intermediate and large, and up to 2 in. on the largest plates. It is not generally desirable to use recessed plates for thicker cakes than these on account of the strain on the cloth imposed by the raised rim.

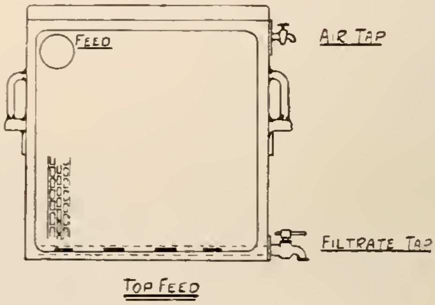
The liquor enters the chamber under pressure, the solid portions being retained by the cloth, while the fluid portions pass through and drain behind the cloths through the grooves or corrugations to the exit ports. They pass finally into the filtrate trough by simple spouts if rough filtration only is in question, but more usually taps are fitted by means of which any one chamber can be isolated if the filtrate from it is muddy, due to faulty cloth. Taps are also needed for certain arrangements of washing presses. Where a liquor must not come in contact with air, or it is desired to raise it to a higher level direct from the press, it can be taken away by an enclosed outlet passage.

Recessed plates usually have a central feed, and for most purposes this is as suitable as any. It is sometimes preferred in the top corner in cases where the cake is apt to be slimy round the feed passage. By this arrangement the moist portion of the cake is readily isolated from the bulk, which is firmer and drier. Putting the passage in a corner in this manner, however, is apt to cause more strain on the cloth in a recessed type press. Bottom feed is useful if a solid cake is not to be formed, as the liquid contents of the cells can be run out before opening the press, but where the solids have a strong tendency to settle it may become choked, especially if the flow is slow.



Enlarged sectional elevation.





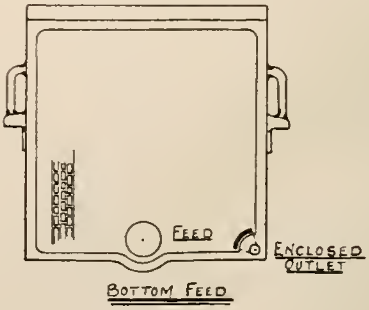


Fig. 1.

Cast-iron recessed plates. Types of feed inlets and filtrate outlets.

When heavy suspensions are being dealt with, top feed is therefore valuable. In cases of this kind two feed passages are sometimes arranged at different heights so as to get the maximum consolidation of cake. It should be realised that the path of each particle is determined by definite stream lines, in conjunction with its own tendency to sink or float. Thus, with bottom feed, no large heavy particles may reach the top of the plates, unless the stream line flow is strong. There is no agitation worth speaking of in the press itself, as the small amount which may occur near each inlet port is quite powerless to cause redistribution if selective settling has been allowed to occur.

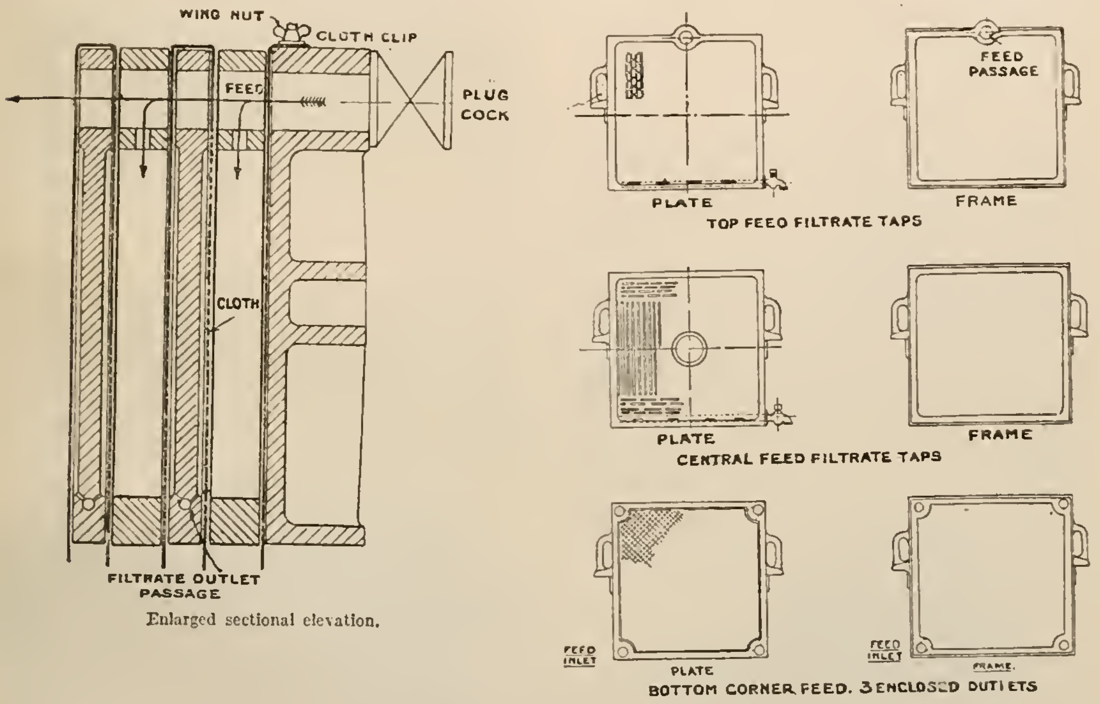
The plate and frame type of press (Fig. 2) is suitable where very thick cakes are to be formed, as in this case the plates themselves are flat, and the chamber is formed by hollow frames being placed between them. This type of press is also suitable for materials which tend to rot the cloths, as the latter lie quite flat on the plate; it is a necessity if filter paper is to be employed. It must be used where very thick cakes are essential, but is not suitable for thin ones or materials of a lumpy or uneven nature, as the feed ports are generally taken in through the rim of the frames, and are thus restricted in area. On a small press, say 25½ in. square, frames as thin as ⅝ in. can be used if the feed is of a more or less liquid nature throughout the operation; ⅞ in. or 1 in. frames are usually quite thin enough, and where chambers exceed 36 in. square it is preferable that these should be thicker if possible, so that the port may be of a proper width. When handling materials which tend to deposit a very hard, firm cake, an internal feed is sometimes desirable, to obviate choking and uneven pressures.

In the majority of cases passages arranged externally to the cake are highly satisfactory, as they isolate the moist unfiltered liquor from the cake, and the feed holes in the cloths are clipped automatically by the joint surface of the plates and frames, and so need no sewing or special clips. The usual position for the passage is at the top centre of the press, which allows little opportunity for displacement of the feed holes in the cloths either by accidents or shrinkage. Another position in general use is in the side of the press at a little above or somewhat below the centre. Such passage is not so liable to get blocked by settlement as one in the bottom of the press, and is in a favourable position for consolidating the cake.

For varnishes and gummy liquors which flow with difficulty these presses are sometimes made with four passages, one at each corner of the chamber; one of the lower passages serves as feed inlet and drain while the other three act as filtrate outlets, being joined together at the head of the press. By this arrangement the liquor has a minimum distance to travel through the grooved surface to get to the outlet passage. Further, the upper passages ensure a free escape of the air from the chamber, whereas it might otherwise have difficulty in passing through the joints when these are under heavy pressure and the cloths heavily gummed up. Sometimes presses are provided with special air passages or taps for this purpose, but except for washing presses it is rarely that these are necessary.

Press plates are usually made in cast iron for neutral or alkaline materials, or in wood for acid liquors, or for dealing with such materials as colours, which might be spoilt by contact with iron. They can, however, be made in bronze or aluminium, or may be covered with hard lead or vulcanite. In the latter case the vulcanite is usually supported by thin steel sheets and the joint surfaces are made of softer rubber. Such a press will deal with strong hydrochloric acid.

Wood plates have been made of a variety of materials, but on the whole the coniferous woods are the best, as these have the greatest uniformity of structure, suffer the least disturbance from medullary or transverse rays, and have less sapwood and small shrinkage. For strength, cheapness, and service generally good pitch pine is difficult to equal. Presses of this material have been reported as withstanding very satisfactorily 8% hydrochloric and 30% sulphuric acid. The author has reports where even 10% or stronger hydrochloric acid is being used, but it is preferable not to go above 4% if at all possible. Timber has to be carefully selected for such work. After the best quality wood has been bought some 20% or 30% has usually to be rejected on first inspection, with further rejections after it has been worked



Enlarged sectional elevation.

FIG. 2.
Flush plates and frames.

up. Oak makes good press plates, and is especially good for withstanding acetic acid, while teak is sometimes reported as being more resistant to acids than pitch pine, though it is more expensive. Beech, maple, or sycamore are used as substitutes, but the previously mentioned woods are preferable. Cypress is also used, more especially in the United States. Very much depends on the quality of the wood, straightness of grain, freedom from knots and shakes, and specially freedom from sap on the filter surface. Impregnation is of doubtful value for increasing resistance to acids. Of preservative mediums paraffin wax (or ceresin) is perhaps the best. It is of importance to keep wood presses closed and moist when out of service. They should be sluiced down before dead periods and kept filled with water. Shrinking is thus avoided, and there is no opportunity for weak liquors left on the plate surfaces to concentrate by evaporation and attack them. Further, in starting up a new press the stay rods should not be too tightly screwed up, but a little allowance made for the necessary expansion of the wood when first moistened. These rods can gradually be tightened up after a little use, but should not be allowed to cut into the wood.

There are various types of filter surface, ranging from very fine straight grooves to comparatively coarse pyramids or lozenges. The first and most important point is that the channels should be sufficiently deep and narrow not to be closed by the sag of the cloth. In the second place the cloth must be adequately supported with a minimum amount of dead space, though, providing the channels are free, the percentage of dead space within reasonable limits seems to make no appreciable difference in practice. Finally, smoothness and absence of sharp corners is a factor of no little importance. Covering the surface with perforated plates is only to be recommended in special cases where the adequate supporting of the cloth has to take precedence over every other consideration. Coarse-mesh gauze makes a good support. But any covering adds to the work of keeping the filter surface clean. For very viscous liquors the supporting of the cloth may have to give way to the necessity for providing very free flow at the back of the cloth, with consequent wider gaps between the supports.

In large presses, say over 36 in. square, where very high pressure or uneven filling of the chambers may be encountered, it is necessary to provide the surfaces of the plates with bosses to act as additional supports. Such bosses may be cast upon the face of the plates in the first instance, though in some cases it is preferred to add specially made bosses screwed on to the face. The great essential is that the height shall be accurate and the business surface carefully rounded off. Further, the slope must be gentle to avoid injuring the cloths. Unless absolutely necessary, such bosses are preferably dispensed with.

The design of handles requires more care than is often given. There should be ample room to get the hand in easily without any trapping or fouling. In the case of heavy plates rollers are usually fitted, and in some cases a special carriage is even arranged on which the plates can be run along the press. Some users prefer the handles to be kept very low (*cf.* Fig. 40), as they state that the plates are then drawn back more evenly, and there is less tendency to tilt, and cut the cloth between the edge of one plate and the face of another. It is doubtful, however, whether there is any real difference in actual practice, as the ordinary type of handles are very convenient to grip.

For feeding the press and for washing purposes cocks are better than the ordinary type of valve. A useful valve, however, has the screw entirely clear of the stuffing-box, and the valve itself is carried through the stuffing-box so that nothing can get at the back of it to jam. Occasionally presses are fitted with a rail running right along one side, a little below the bottom of the plates. This and the gutter serve as supports for draining trays which catch any drip, a specially useful arrangement in the case of old wood presses. All the liquor then runs to the trough, and the floor is kept clean.

A "dead" plate, or "cutting-off plate," is a desirable fitting if batches of varying size are to be dealt with, some of which may be insufficient to fill the whole press. Such a plate has one working face only, and is sufficiently strong to withstand the unbalanced end pressure. It can be placed anywhere in the press, permitting a few chambers to be used while the rest are isolated. In default of this sufficient space may be made for the tailings of a batch by emptying a few chambers at the feed end only, leaving the remaining cakes to be removed when these have been filled again, but in large presses this is a cumbersome proceeding.

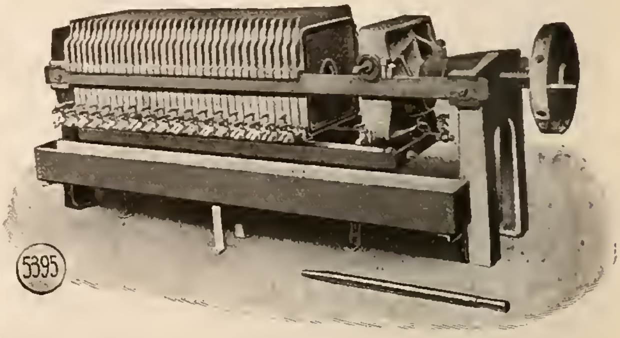


Fig. 3.

The question of side rods has had some attention from all makers, but it is difficult to say where the greatest advantage lies. Flat rods may be used on somewhat longer presses without support, but the plates slide more readily on the round bars, and these can be conveniently trussed in some types of press. It is important that sufficient space be left between bars and plates to give convenient room for the edges of the cloth. The plates are kept in position by distance pieces, though in the case of flat bars the handles on one side are sometimes provided with a notch for this purpose. This, however, is liable to jam if the plates are not moved back perfectly evenly.

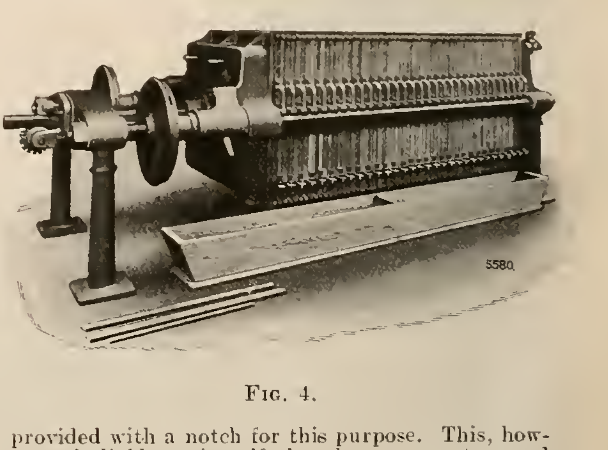


Fig. 4.

After the plates themselves, perhaps the most conspicuous feature is the closing gear. There are a great variety of designs, both hand and power operated, but on the whole the simplest types are preferable so long as they will give the required pressure.

The usual type of gear for small presses is the centre-screw pattern (Fig. 3). This is in use for wood presses up to 36 in. or more in size, working at pressures up to 30 or 10 lb., but is preferably limited to the 25¼ in. size and under. Such a gear will readily close an ordinary 25¼ in. cast-iron press against 100 lb. pressure. A swinging distance piece on the loose head enables the latter to be drawn back after the tightening screw has been released by a couple of turns. The head may be arranged to run on wheels, and in the case of larger presses these are often on a common axle, fitted with a handle to give quick movement. The centre of the head is also recessed so that it can be pushed right up over the tightening screw and further play obtained. In some forms, instead of having a distance piece, the end standard is fitted with a pivot which carries the screw, so that as soon as the latter is released it can be swung up right out of the way. A common means of tightening is by a bar inserted into holes on the spindle head, a method which gives a very sure grip. Ratchet devices are, however, in common use. In a somewhat special variant of this form the screw is stationary, and a nut which revolves on it transmits the pressure through levers to half a dozen arms or rods which bear on the press head. These arms can be released and shot right back when it is desired to empty the press.

Another gear suitable for larger presses consists of a rack, fixed to the loose head, engaging a pinion on the end standard (Fig. 4). By this means the head is rapidly moved backwards and forwards, while the side rods are screwed and carry wheel nuts which are tightened by levers against swinging distance pieces. Such a device will adequately close a 38 in. cast-iron press against 100 lb. per square inch or even more. It is necessary to attach the rack to the loose head by a joint, as it is found that there is slightly more accumulation of dirt at the bottom edges of the plates, and this causes the head to tilt.

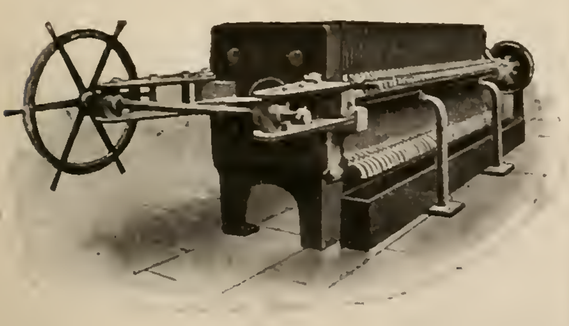


FIG. 6.

Another form which is often employed is the spur wheel and pinion gear (Fig. 5). This is generally similar to the centre-screw type, but the screw is driven by a large spur wheel engaging with a pinion, giving an additional multiplication of from four to eight times according to the size of the press. The pinion is fitted with a large handwheel for rapid manipulation, and final tightening is accomplished by levers. Sometimes both spur wheel and pinion are fitted with elaborate devices for slow and quick movement, but according to the author's observation the simpler arrangements are better, as the more elaborate are apt to consume time without giving any better closing. Such a spur wheel and pinion device permits the use of trussed side bars in the case of a long press. This arrangement obviates the necessity for supporting pillars, which may interfere somewhat with the removal of the cake from under the press. Such a gear is suitable for most duties on either wood or iron presses, but a more powerful one is the toggle lever pattern (Fig. 6). This is suitable for large wood presses up to about 48 in. The arrangement of the loose head is like the rack and pinion closing gear except that the pinion has its own spindle and hand wheel for ease in operation. The side rods, however, are not fixed to the heads but are attached to the short arms of a pair of levers which have a hinged connection to the fast head, and a screw and hand wheel, by means of which their long extremities are drawn together. A very large mechanical advantage is thus obtained. The merit of the device is the ease by which one man can put on the final tightening pressure simply by operating the hand wheel without the use of levers. The arrangement of the gear is such that perfectly even pressures are applied to both sides of the press.

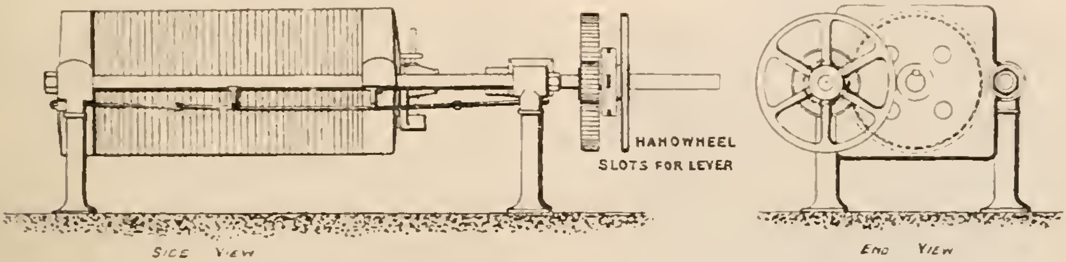


FIG. 5.

38 *in. plate and frame filter press. Spur wheel and pinion closing; and trussed side rods.*

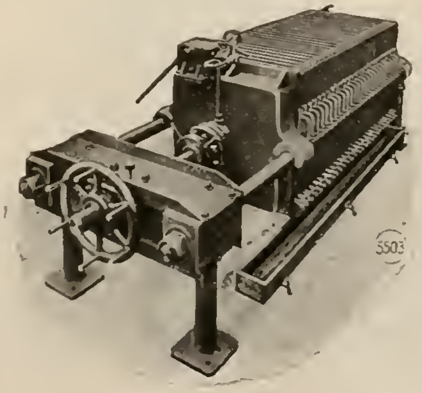


FIG. 7.

Yet another form of hand-closing gear utilizes a small hydraulic pump mounted on the loose head (Fig. 7). This is suitable for very high pressures or large presses. It is somewhat costly, and takes longer to operate, but puts on a perfectly definite amount of pressure, which can be regulated exactly by the gauge. In the instance illustrated the head is moved up and down by a centre screw and large hand wheel, and the hydraulic ram is housed in the centre of the loose head and engages the end of the screw. The ram carries a lock nut, which is screwed up when the pressure has been put on, preventing the press blowing or leaking if the pump pressure drops. Pneumatic closing (Fig. 8) saves labour, in so far that the head can be drawn back simply by manipulating a valve, and by the same means may be pushed back again, carrying all the empty plates with it. This is a very valuable feature in large installations having simple recessed plates in which the cloths and passages require no attention during the replacing of the empty plates. Large numbers are in use for sewage sludge. It should be remembered, however, that the actual pressure is not put on by the ram but by the wheel nuts on the side rods.

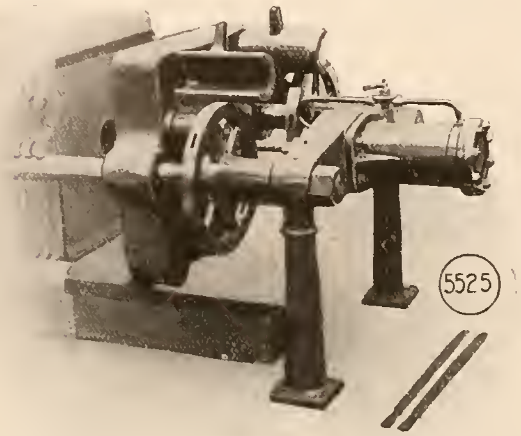


FIG. 8.

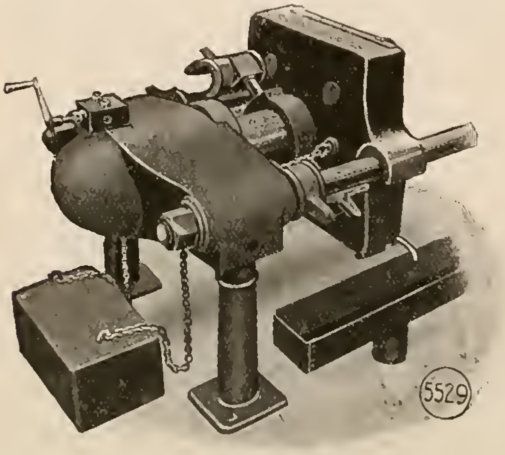


FIG. 9.

The hydraulic closing gear shown in Fig. 9 has an additional advantage in that the final tightening is done mechanically, the only handwork being the operation of the locking device, which is a safeguard in case the water pressure drops. In the instance shown this locking gear is very similar to the previous tightening gear, except that only hand pressure has to be put on the lock nuts. The loose head may be drawn back either by a special hydraulic cylinder or by weights. Where the space is small, or it is not possible to cut through the floor to accommodate the chains carrying the weights, special devices can be arranged on the top of the end standard so that the weights are kept above the floor.

Trays are often provided to go under the press, thus saving labour in the removal of the cake. At times the whole press is arranged to stand in a special trough which completely surrounds it, and serves to isolate the cake from the rest of the floor.

The filtrate trough is sometimes arranged with a longitudinal division plate. The taps are then fitted with rubber extensions or swivel nose-pieces, by means of which clear filtrate can be run to one division and muddy to another. Separate run-off valves may be also provided for washings. In the case of washing presses it is usual to make the trough larger and provide a plug or cock, so that it can be used as a measuring tank for the wash water.

Where presses are installed on an upper floor, discharging to a lower one, steel shoots are fitted to the fast and loose heads. If volatile liquors or those liable to give out dangerous vapours are being dealt with the press can be fitted with a base on to which a cover fits, the joint being made by means of a water seal or clamps (Fig. 10). In this case the press is arranged with a continuous outlet passage, and the feed and any other passages are controlled by external valves.

For strong caustic liquors, which cause ordinary cotton cloths to perish rapidly, or for delicate cloths, the plates can be arranged so that the cloths do not pass over the joints, but the latter are made by rubber or other rings let into grooves all round each rim in alternate plates (Fig. 11). All the plates are then provided with a recess all round the inner side of the rim, into which the edge of the cloth is laid and made fast by a packing ring being caulked in. Alternatively the cloth may be secured by being clipped in by a joint plate which is held down by screws. Further, in such instances a perforated plate is laid over the usual corrugations, thus still more reducing the strain on the cloth, which has then a perfectly flat surface on which to rest. This arrangement effectively lengthens the life of the cloths, as the greatest wear usually takes place at the nip of the plates. Further, if the cloth is kept well supported at every point, so that a spud cannot readily be pushed through it when the cake is being cleaned off, it may readily last, even when apparently quite rotten. A perforated plate or grid is sometimes laid over the top of the cloth. This protects it from the spud, and prevents a rotten cloth from being torn away by the weight of adhering cake. It will be realised that recessed presses of this type cannot be constructed to make thin cakes, but are suitable for thick ones from, say, 1½ in. upwards.

Where quantities of non-viscous liquors containing very small amounts of very fine matter in suspension are to be filtered special presses are in use. The plates are not provided with a filtering surface of the usual type, but are filled with cakes of finely divided cotton pulp or other suitable material. Such a press would filter many liquors at the rate of about 4 galls. per sq. ft. per hour, and when it became clogged the pulp would be knocked out of the chambers, washed in a special washing machine, and then pressed firmly into position again by means of a special hydraulic or screw press. A usual method is to prepare the pulp cakes during the filtration period and then lay or press them in position in the specially designed plates at the end of the run, when the old pulp has been knocked out for washing.

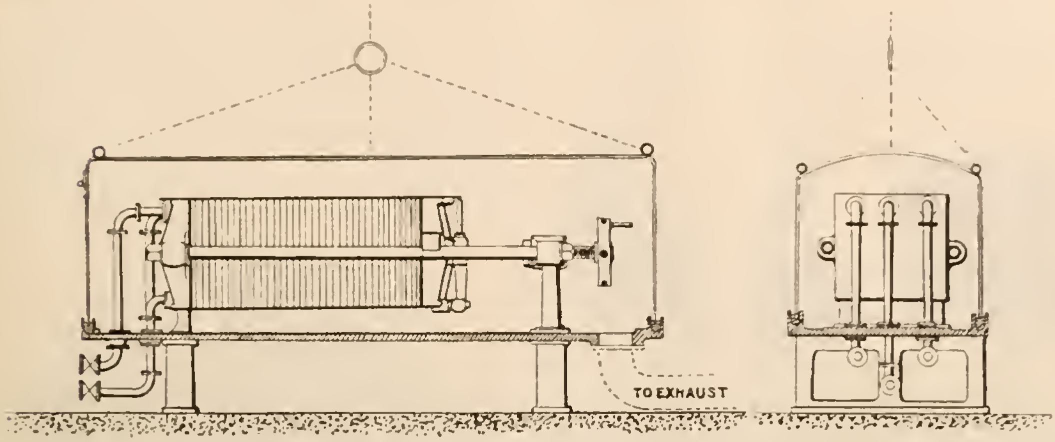
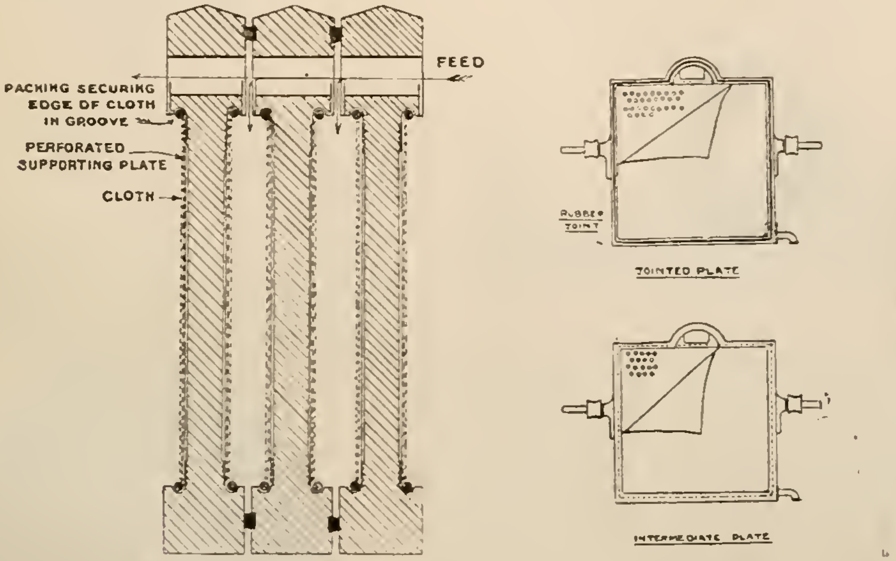


Fig. 10.

Enclosed filter press.

25½ in. square; washing type; enclosed outlet; C.I. tray and sheet iron hood; feed and wash pipes taken through tray with device for air flushing at end of operation.


FEED
PACKING SECURING EDGE OF CLOTH IN GROOVE
PERFORATED SUPPORTING PLATE
CLOTH
RUBBER JOINT
JOINTED PLATE
INTERMEDIATE PLATE

Enlarged sectional elevation.

Fig. 11.

Plates with inserted cloths.

Choice and Care of the Filter Cloth.

In recessed plate presses double cloths (Fig. 12) are often used. These cloths are stitched together at the edges of the feed opening, and one cloth is passed through the feed-hole in the plate, both halves being then spread over the filter surface and fastened at the top by clips or pins, or they may be stitched. In such cases the top of the plate carries a projection or fin for convenience in fastening the cloth. This method of fixing is suitable for most purposes, and is strongly recommended where cloths are thin or have often to be taken off and washed. For certainty in obtaining clear filtrates with fine precipitates there is nothing to equal cloths with sewn openings.

Another way of clothing the press is to take a strip of cloth, long enough to cover both sides of the plate, with two holes cut in it corresponding to the feed passage. This is hung over the top of the plate, and the joint round the feed passage is made by clips. A very usual form of clip, the "bayonet" pattern (Fig. 13), is in halves, one of which is provided with inclined projections, which engage with lugs on the other one, so that on giving a slight rotation the two halves are pressed firmly on to the cloth, making the joint. This form is the quickest to apply, but the screw pattern (Fig. 14) is to be preferred as the most secure. It is, however, rather more costly. Such clips save a good deal of time and expense in stitching round the feed opening, and are useful where the cloths have to stay in the press till they are worn out. They are, nevertheless, apt to be misused. For instance, where cloths have to be taken frequently from the press for washing purposes it will be found that the double cloths previously described are much more quickly removed and replaced. In one case of a 38-in. recessed plate press having 26 chambers, using thin cloths, it was found that the use of cloth clips entailed an additional three-quarters of an hour in stripping and re-clothing as against the use of double cloths with sewn centres.

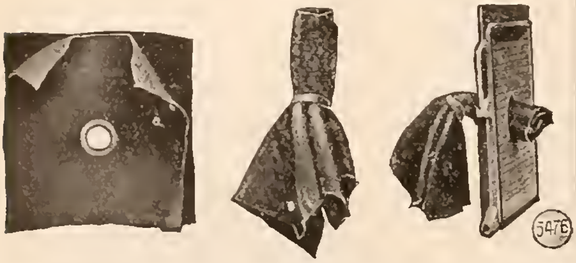


Fig. 12.

Then, again, with thin cloths it is sometimes difficult to get clips to make a secure joint.

In frame presses cloths of double length may be hung over the plate without any special attachment or stitching, but it is best to sew them on if there are many passages in the plate rim and the cloth is to remain on the plate for some time.

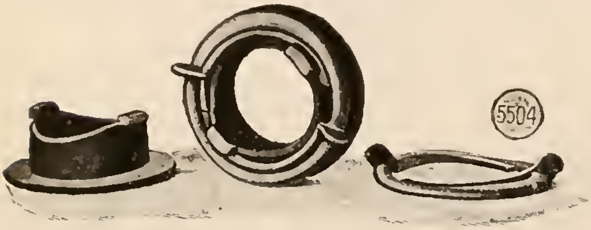


Fig. 13.

Still another method is to use single cloths, caught by clips or pins at the top of the plate. The cloth top is sometimes eyeletted and engages with hooks of adjustable height. This permits ease in fixing when replacements are frequent, but sewing is the best if well done.

Fig. 15 shows a comparatively coarse precipitate of calcium sulphate (magnified 18 diameters), while Fig. 16 shows to the same scale a tightly woven 18-oz. twill cloth, with no spaces between the threads, such as is used for filtering substances of a fine uniform nature, the particles of which would not be perceptible except at a much higher magnification. Such a tightly woven cloth is a necessity in some cases, say for many dyestuffs, but would be quite unnecessary for such a precipitate as calcium tartarate (Fig. 17), in which the crystals range from comparatively large, say 0·1 mm. side, to very small.

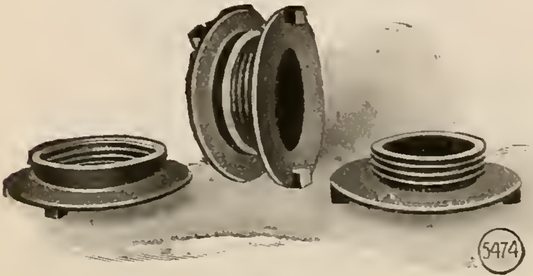


Fig. 14.

An open jute cloth (Fig. 18) served very well for this purpose, though even after careful shrinking many holes of 0·25 mm. side are apparent. In such a case the first fine particles pass through the cloth, while a layer of the coarser ones is rapidly built up on it, the spaces between them being so fine that even the smallest are caught. The first runnings are muddy, but it is little trouble to return them to the press, while the cloths retain their free-flowing qualities for longer than if an attempt had been made to get clear liquor at the start. The spaces between the threads in the shrunk cloth may be larger than any of the particles, but apparently the latter tend to jam, and are assisted in this by stray fibres from the threads.

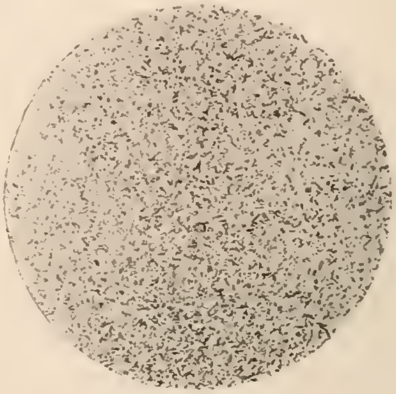


Fig. 15.

Sulphate of lime (÷18).

In dealing with caustic soda, about 5% free alkali is as much as a cotton cloth will stand to give a reasonable life in ordinary types of press. Somewhat stronger liquors may be filtered if the cloth is treated with heavy naphtha or green oil, especially if care is taken not to allow the caustic liquor to dry into the cloths. In one case which came under the author's notice good results were reported consequent on the removal and soaking of the cloths every week-end. This was additional to the use of an oil preservative. Some users report having employed twill cloths with 10% free alkali, the life being about three weeks, but it is desirable, if possible, to keep to 3 or 4%. A similar percentage of sulphuric acid should be satisfactory, though some users report that cotton cloths withstand 7% to 8% economically. Twill cloths are perhaps in

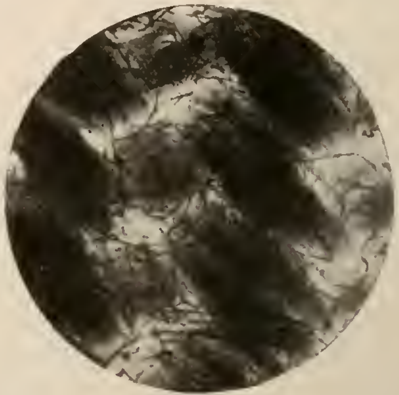


Fig. 16.

Twill cloth (÷18).

greater favour than the chain weave, though some users say the latter are stronger and give finer filtration. As far as the author can judge there is not much difference between the two, providing the cloths are properly chosen. The mercerising effect of alkali should not be forgotten, and if a cloth is to be used for alkaline liquors it is best not too tightly woven, as otherwise it may become relatively impervious. Further, for corrosive liquors those with the thicker threads seem to give the best results, as they will hold together in the press even after they have become quite rotten.

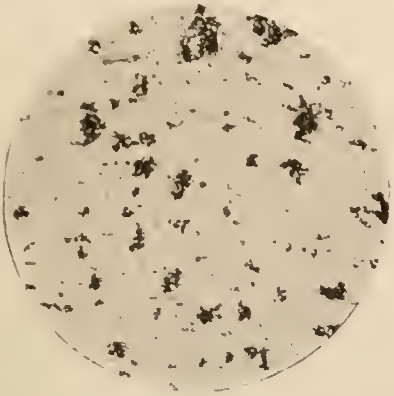


FIG. 17.

Calcium tartrate (+18).

Linen is employed for the more open-mesh straining cloths, which are sometimes useful in the filter press when dealing with comparatively coarse suspensions in liquors containing casein or other substances, which would rapidly render a more compact cloth impervious.

Jute and hessian cloths or sacking are often used instead of cotton, and are quite good with weak alkaline liquors, providing a very fine, tight weave is not requisite. These cloths are also used as under-cloths, a strong coarse cloth being used to support a thin, tightly woven twill. This helps to protect it from damage at the joints, especially where there is likely to be trouble with rusting. Further, in such an arrangement the upper cloth may be sufficiently closely woven to stop very fine particles, and yet its thinness prevents its becoming too rapidly impervious. It is readily removed and washed, while the under-cloth, though strong and heavy, can be coarse enough to run freely for a considerable period. Filter paper may be used instead of a fine upper cloth. It must be well supported, and should be of the crinkled variety, as this can give a little to the sag of the cloth. Paper has unfortunately the disadvantage that it may come away with the cake, but this is of no consequence if only the clear liquor is required.

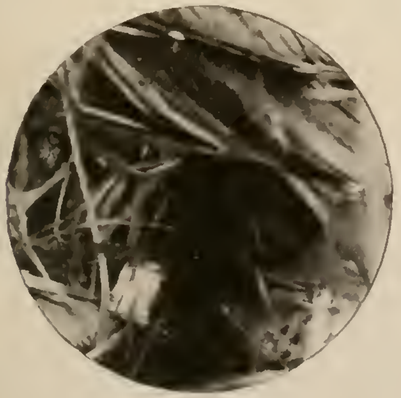


FIG. 18.

Jute cloth (+18).

Cloths with a swansdown surface are used for such purposes as the filtration of yeast, and are then protected from clogging by a superposed cloth of strong twill. It is, however, open to question whether they are any better than good twill cloths.

For strongly acid liquors there are a variety of cloths to choose from. One firm reports that camel's hair is satisfactory up to 30% sulphuric acid and 10% hydrochloric acid, while horsehair would stand 10% hydrochloric acid, but is not good for sulphuric acid. The same firm have used woven copper wire for 12% to 14% hydrochloric acid with a life of 4½ months, while the same wire cloth was satisfactory with 30% sulphuric acid. Wool or felt cloths will generally resist from 15% to 20% sulphuric acid, but are of little use for hydrochloric acid.

Asbestos will withstand any strength of acid or alkali likely to be put into a filter press, but is apt to deteriorate when handled, and, further, is difficult to obtain in a sufficiently finely woven form. The qualities vary a great deal, and it is well to make careful tests before buying in quantity. On the whole, for strong acids, a good camel's hair cloth, if treated properly, has much to recommend it. A great deal, however, is sold as camel's hair which is of quite other origin.

With regard to wire cloth, in one case which came under the author's notice a twill nickel cloth was used for removing sodium sulphite from mother liquor up to 50% causticity. A sample of such cloth, 360-mesh, appears quite impervious to light, except when held at certain angles.

Cloths should not be allowed to dry on the press when out of use, but should be rinsed free of corrosive liquors and retained solids and kept moist. The former will cause rotting if allowed to dry in, while the solids will become hard and impervious. Repeated drying and wetting accentuates shrinkage. In a well-woven filter cloth for dealing with materials such as dyes, the threads, though stout, should be packed so closely that they touch one another at every point. Then again the cloth should be as free as possible from parallel dark streaks or "reed" marks or lighter portions indicating missed or broken threads. Occasional dark specks on a cotton cloth do not, however, signify.

Some users prefer to have the cloths shrunk before they are put on the press. With a well-woven cloth with small shrinkage this is not necessary with centre feed, top feed, or passages in external lugs. Where, however, there are ports near the bottom of the cloth it is usually wise to shrink the cloths before use. It should be noted that the holes can be cut and the press clothed while the cloths are wet. In some cases boiling water should be used, but this, however, is not usually necessary, although it would have the effect of causing a cloth to filter clearly when it otherwise might not do so. The question of shrinkage is a difficult one, and depends on the weaving, though it may be said that the less compact cloths may shrink anything up to 7 or 8%, while more closely woven ones may shrink as little as 2½%. Something depends, too, on the quality of the cotton and the quality of the weaving, and instances are not unknown where two cloths of apparently precisely the same quality, texture, and weave may shrink very differently. On the whole, such valuable cloths as camel's hair are best soaked in mother liquor at the correct temperature before being put on the press, as if shrinkage occurs while the cloth is tightly clamped its life may be seriously impaired on the first occasion of use.

In dealing with many food products, and also in cases where the cloths become rapidly clogged, it is necessary to remove them at regular intervals for washing. The ordinary type of washing machine (Fig. 19) consists of a vessel or outer casing within which revolves a perforated drum in which the cloths are placed. This drum is fitted with beaters, and revolves three times in one direction and then three times in the other to prevent roping of the cloths. The washing medium may be a weak solution of soda which can be heated by live steam, or a solvent may be employed. Another form of this machine has an independently driven squeegee inside the drum which acts as a shelf or lifter for part of the time and during the remainder compresses the cloths against a beater fixed to the drum shell. Another type of washer (Fig. 20) consists of a tank constructed in wood or iron. A squeezing block runs the whole length of the tank, and is suspended from hinges fixed on pillars attached to the machine. There are false sides to the trough which are sprung in such a way that they can give a little to the action of the squeegee as it rocks from side to side. The cloths are placed concertina fashion on either side of the squeegee and are first compressed and squeezed against the side of the trough and then released, being allowed to fall over and open out, after which the process is repeated. Such a washer is excellent for squeezing out obstinate dirt with a minimum of wear on the cloths.

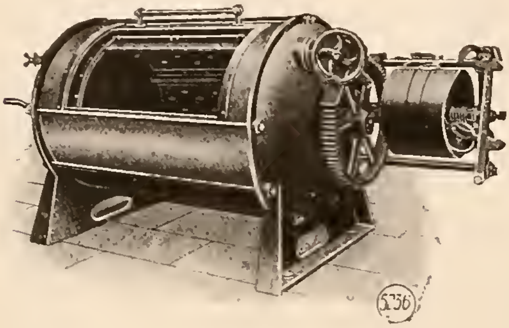


FIG. 19.

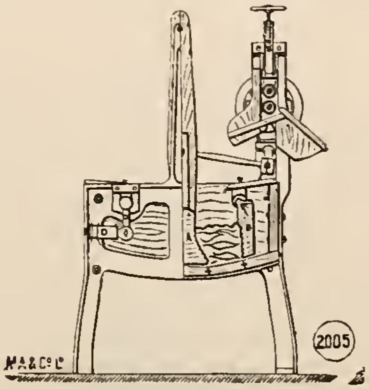


FIG. 20.

The simplest device is a tank fitted with a steam circulating injector. This is satisfactory with light cloths and readily soluble precipitates.

Some theoretical and practical considerations in regard to rate of filtration etc.

The design and efficient working of a filter-press installation depends on the material, the treatment desired, and various factors of a mechanical nature.

The questions relating to the material comprise:

1. Quantity per hour.
2. Chemical properties.
3. Suitable temperature for filtration, and viscosity of liquor at that temperature.
4. Percentage of solids.
5. Size, shape of grain, and hardness of suspended particles.
6. The permeability of the deposit as affected by pressure, time, and flow.
7. Nature of first deposit on cloth.
8. Does deposit bind on to cloth, or will it fall readily away?

In regard to treatment we must consider:—

9. What extent of clarification is desired.
10. Is the cake or the filtrate of most value, and is a firm cake to be formed?
11. Must the material be washed, and, if so, how thoroughly?
12. Is it to be air dried in the press?
13. Are any special steaming, heating, or cooling arrangements needed.

The mechanical and other factors include:—

14. Practical chamber thickness.
15. Practical maximum pumping capacity.
16. Effect of various influences on the length of the discharging period.
17. Relative cost of various arrangements.
18. General layout in relation to remainder of plant.

It will be seen that it is not usually practicable to obtain exact information on the whole of the physical data involved. Fortunately trials with a gallon or two of liquor will enable the following data to be settled:—(*a*) Suitable cake thickness; (*b*) working pressure; (*c*) cloth; (*d*) time to make a cake, or rate of filtration; (*e*) nature of aids to filtration, if required.

Usually one or two tests will elucidate these sufficiently to allow those with proper experience to approximate to the most perfect scheme.

We will now consider various factors in detail, commencing with a mathematical treatment of such as are amenable to it. This is helpful to clear thinking, for while nothing can be a substitute for experience, it is not always realised what influence such factors as cake thickness and length of press have on output and economical results.

Where the solids build up with a perfectly rigid granular structure, the rate of flow is proportional to the pressure. It also varies inversely as the resistance of the cloth etc. and that of the deposited cake. The former is fixed, while the latter increases throughout the operation, being proportional to the total flow and the percentage of suspended solids. Sperry defined unit resistance as that which allows a flow of one gallon per sq. ft. per hour under a pressure of 1 lb. per sq. in. In the case of the solids a deposit of 1 in. was assumed in fixing the unit. The rate of deposition was settled as being unity when one gallon of filtrate flowing through 1 sq. ft. left a deposit of 1 in., there being 1% of solids in suspension. On these assumptions he derived the formulæ:—

$$\frac{dQ}{dT} = \frac{P}{R_m + Rt'} = \frac{P}{R_m + \frac{RQX}{K}} \quad \cdots \quad \cdots \quad (1)$$

$$T = \frac{RX\,Q^2}{2\,PK} + \frac{R_m\,Q}{P} \quad \cdots \quad \cdots \quad \cdots \quad (2)$$

$$Q = \sqrt{\frac{2\,PKT}{RX} + \left(\frac{KR_m}{RX}\right)^2} - \frac{KR_m}{RX} \quad \cdots \quad (3)$$

where P = pressure. Q = gallons discharged liquor. T = time in hours. dQ/dT = instantaneous rate of flow. X = percentage of solids in liquor. t' = thickness of deposit in inches. K = rate of deposition. R = resistance of one inch of solids. R_m is resistance of cloth. (*Cf.* Chem. and Met. Eng., 1916, 15. p. 198—203.)

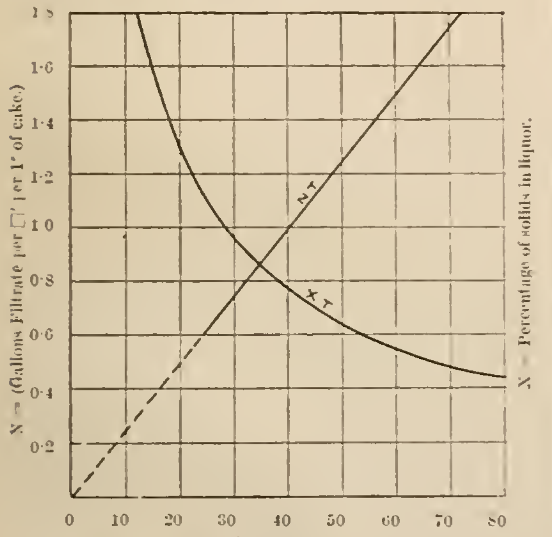
These formulæ all apply to constant pressure conditions, and do not include the period of diminished flow during consolidation of the cake. Since, for any series of such tests P, R, and R_m are readily kept more or less constant, while X is apt to vary, we may write $A = R/2P$, $B = R_m/P$, and $N = K/2X$ where N is the number of gallons to form 1 in. of cake; *i.e.*, to deposit a layer ½ in. thick on each cloth. A, B, and N are very readily found by a trial filtration in an experimental press, and we may simplify the original formulæ as below:—

$$\frac{dQ}{dT} = \frac{1}{\frac{AQ}{N} + B} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1a)$$

$$T = \frac{AQ^2}{2N} + BQ \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2a)$$

$$Q = \sqrt{\frac{2NT}{A} + \left(\frac{NB}{A}\right)^2} - \frac{NB}{A} \quad \ldots \quad \ldots \quad (3a)$$

Such formulæ apply with very fair exactness over the greater part of many time discharge curves, providing these are taken under constant pressure conditions. We shall be mainly concerned with number (2a), as (3a) is only required when the question of cake formation is of no importance. The rate of flow dQ/dT diminishes as time increases, as is well shown by the diminishing curve (Fig. 26) described later.



Relation between time to form a cake and the strength of the mixture.

FIG. 21.

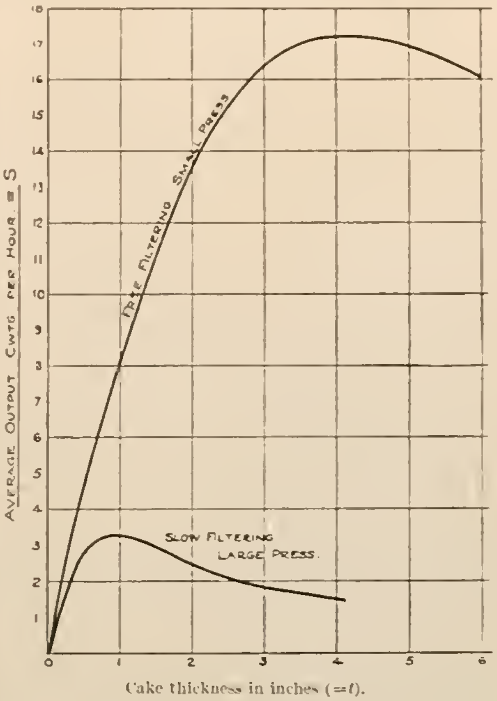
We are now in a position to develop the formulæ with a view to applying them to the solution of the relation of the average rate of flow to the dilution of the mixture; of that of cake thickness to output; and of length of press to capacity—both absolute and in relation to prime cost. For the sake of simplicity we shall not consider closely the effect of the time required for final consolidation, or for filling the press initially, where the pump is of limited capacity. Nevertheless, the simple outline below will illustrate sufficiently the general tendencies.

Let F_1 be the time to form a 1 in. cake, the amount of filtrate being N gallons by definition. If a cake t inches thick is to be obtained, the amount of filtrate is Q = Nt, and substituting this in (2a), the time F_t to form it is given by—

$$F_t = \frac{AN^2t^2}{2N} + BNt$$

$$= N\left(\frac{At^2}{2} + Bt\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

From equation 4 we see that the time to get a cake is proportional to N (or the volume of filtrate to make a cake) providing the thickness remains constant. It is not quite inversely proportional to the percentage strength of the mixture (although in many cases it may be nearly so) since a certain amount of liquid remains in the cake. Fig. 21 shows the theoretical relationship for a freely filtering material building a thick cake. The relation N·T is a straight line, while that of X·T is a curve giving values of T nearly inversely proportional to the value of X. The proportionality would be exact if X, in Sperry's formulæ, were calculated on filtrate, and not on total liquor. In practice, however, both these relationships may be somewhat altered by the greater consolidation of the cake when formed from weak mixtures, which may cause the time to form it to be lengthened out of proportion (*cf.* Fig. 25 described later).



Relation between cake thickness and output for two extreme cases.

FIG. 22.

We will now consider the question of best cake thickness.

Substituting M = AN/2 and

m = NB, then

$$F_t = Mt^2 + mt$$

$$F_1 = M + m \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4a)$$

Let E be the time for emptying, which may be taken as constant for a given size of press, within reasonable limits of thickness. C is the weight of the cakes when 1 in. thick, and S the rate of output over the whole operation, both measured in lb. per sq. ft. of area. Then

$$S = \frac{Ct}{F_t + E}$$

$$= \frac{Ct}{Mt^2 + mt + E} \quad .. \quad .. \quad .. \quad .. \quad (5)$$

S is a maximum with regard to t when dS/dt=0 (see Fig. 22).

We have therefore

$$\frac{d}{dt}\left\{\frac{Ct}{Mt^2 + mt + E}\right\} = 0 \quad .. \quad .. \quad .. \quad (6)$$

$$\therefore \frac{C(Mt^2 + mt + E) - Ct(2Mt + m)}{(Mt^2 + mt + E)^2} = 0$$

$$\therefore Mt^2 + mt + E - t(2Mt + m) = 0$$

$$t = \sqrt{\frac{E}{M}} = \sqrt{\frac{E}{F_1 - m}} \quad .. \quad .. \quad (7)$$

$$t = \sqrt{\frac{2E}{AN}} \quad .. \quad .. \quad .. \quad .. \quad (7a)$$

$$t = \sqrt{\frac{SEPX}{RK}} \quad .. \quad .. \quad .. \quad .. \quad (7b)$$

If we assume that the press is filled by a pump big enough to give the maximum initial rate of discharge, then the time taken to pump an amount of liquor equal to the volume of the press is proportional to *t*. In the above calculation all terms in *t* cancel out, and expressions (7) to (7b) are unaffected. The case is similar if we assume the cakes are washed at a fixed rate of flow. It may however be argued that there is a maximum washing pressure which should not be exceeded. In this case the time W_t for washing a cake t″ thick will be

$$W_t = t^2 W_1$$

where W_1 is the time to wash 1 in. of cake. Similarly it may be held that the time for final consolidation is approximately

$$k_t = t^2 k_1$$

where k_1 is the time to consolidate 1 in. of cake. Equation (5) now becomes

$$S = \frac{Ct}{(M + W_1 + k_1 \times t^2 + mt + E}$$

and the best thickness is

$$t = \sqrt{\frac{E}{M + W_1 + k_1}} = \sqrt{\frac{E}{(F_1 + W_1 + k_1) - m}} \quad (8)$$

$$\text{or } t = \sqrt{\frac{2E}{AN + 2(W_1 + k_1)}} \quad .. \quad .. \quad .. \quad (8a)$$

Fig. 22 shows two curves drawn on the basis of equation (5) for certain conditions commonly met with. The existence of a best thickness for maximum output is clearly shown. In practice the use of this is limited on the one hand by the fact that if the cake is above a certain thickness it may consolidate and become impervious before it is fully formed. This will call for more work in emptying and drying. On the other hand, thin cakes will require more labour per ton, and so a balance of advantage must be struck.

Nevertheless the fact remains that for a material dealt with in a large press taking some time to discharge, thicker cakes are best if they can be formed. A small, rapidly discharged press will give most output with thin cakes if the filtration is fairly slow; if a thick cake can be formed rapidly it may however be satisfactory. This is entirely apart from any question whether thick cakes can or cannot be made. It is purely a matter of securing a proper balance between the filtering and discharging periods. It is also clear that if it is required to wash the cakes at a fixed pressure, or if much consolidation is necessary, then thinner cakes are again desirable.

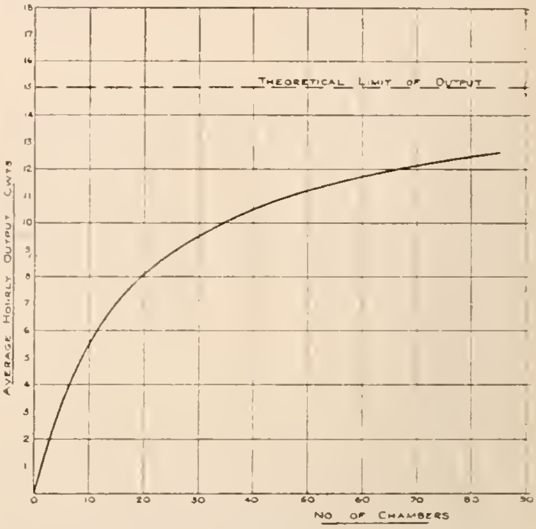


FIG. 23.

Relation of average output to length of press.

The cake thickness, however, is usually settled on practical grounds, determined solely by the thickest cake that can be made of suitable dryness, with a view to reducing labour costs. It is then of importance to know what length of press will give the best results. Let S_Z lbs. be the average hourly capacity of the whole press consisting of Z chambers; C′ the total capacity per chamber in lb. of cake; U the time in operating the closing gear per pressing, and V the time for emptying and reclosing one chamber expressed in hours. Then

$$S_Z = \frac{C'Z}{F_t + U + ZV} \quad .. \quad .. \quad .. \quad (9)$$

Fig. 23 is plotted from this formula, and shows that after a certain length has been reached the addition of further chambers only slightly increases the output. This tends to reach a fixed limit, on account of the longer period the press is at a standstill during each shift. If the cake is built quickly the press must be short or the discharging period will not be in balance. This will not increase seriously the labour cost, since this in the main is taken up in emptying and replacing the plates, only a small proportion being required for working the closing gear and manipulating the valves. It is only where the period of filtration (which in the present case may include washing and air drying) is very protracted, or the material can be emptied very rapidly, that it is economical to use a very large number of chambers. These considerations are strictly borne out in practice.

A further important question is that maximum output should be obtained per unit of prime cost. Let £ be the total cost of the press; $£_F$ the cost of the frame and heads, which includes the first chamber; $£_c$ the cost per additional chamber. Then

$$£_Z = £_F + (Z - 1)£_c$$

The ratio of output to cost is therefore

$$\frac{S_Z}{£_Z} = \frac{C'Z}{(F_t + U + ZV)(£_F + (Z - 1)£_c)} \quad .. \quad (10)$$

Obtaining the maximum value in the usual way, we get

$$Z = \sqrt{\frac{(F_t + U)(£_F - £_c)}{V£}} \quad .. \quad .. \quad (11)$$

Where

S_Z = hourly output in lb.

$£_Z$ = total cost of press. $£_F$ = cost of framework.

$£_C$ = cost of each additional chamber.

C'' = lb. of cake per chamber. Z = number of chambers.

F_t = length of filtration period, including washing etc.

U = time in hours to work gear and valves per operation.

V = time in hours to empty and replace one chamber, including an average allowance for clothing.

Taking a 38 in. plate and frame press, we may assume that the time for working the closing gear, operating valves, pumps, etc., is 20 mins.; and for emptying, say 2½ mins. per chamber. Assuming 3 hours is occupied in getting a cake and substituting current values for $£_F$ and $£_C$, we find the best number of chambers is 32. Hence large units would best be made up of this size press, though for installations of only a single press it might not be worth while to limit the size, which would then be decided by such simple considerations as the number of cubic feet of cake formed per batch of liquor to be handled.

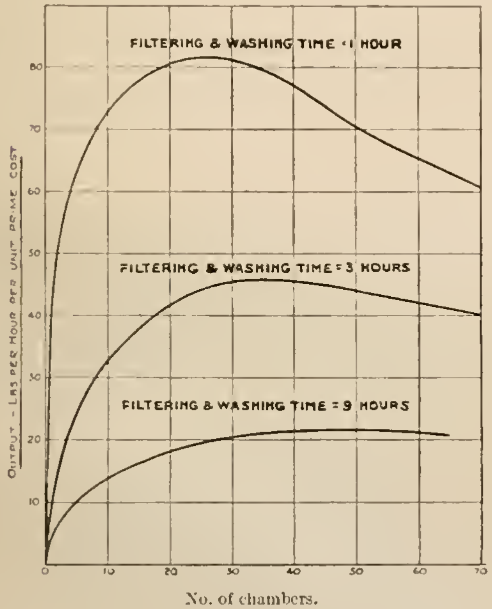


FIG. 24.

Relation of length of press to output per unit prime cost for a 38 in. sq. P. & F. cast-iron press.

Fig. 24 has been drawn on the above basis for three varying periods for filtration and washing. For the slower ones more chambers are seen to be economical, but the slope of the curves varies very gradually for the longer periods. Even when 9 hours are required for filtration we see that it is hardly worth while going over 40 chambers, though the best figure is given by calculation as 54. If discharging were slower, then shorter presses still would be indicated. This would also be the case with more quickly filtering liquors. Recessed presses, or those with wooden plates, would preferably be rather longer, as the cost per chamber is proportionally less.

It is difficult to obtain sufficiently exact figures on which to base a similar calculation in regard to the most economical size of plate. The laws would, however, almost certainly follow the lines of Figs. 22 and 24, and there would be a definite size for maximum average output, and for maximum output in relation to prime cost. The latter consideration would almost certainly indicate a somewhat smaller size than the former. The labour in discharging one chamber may be divided into (a) moving plate, (b) dropping the cake, (c) cleaning the cloths, (d) renewing cloths (e) cleaning passages and ports.

Now (b) and (e) are fairly independent of the size of plate, (a) is more or less so up to a point, after which it increases very rapidly, (c) is directly proportional to the area, while (d) is more or less so, depending on the type of plate.

If the filtering period is long, larger plates will be economical, but in this case one would not expect to find the line of demarcation very strongly defined. If the cleaning of the cloth is the major part of the operation, this will tell against any marked economy in the use of big plates, but if the cakes drop cleanly away, then the best results are likely to be obtained with large sizes. Wood plates, on account of their lightness are economical in larger sizes than iron ones. As a general rule 38-in. or 40-in. plates are quite large enough, and even these do not always show any marked reduction of labour as compared with the 32-in. size. The chief advantage of very large sizes usually lies rather in the saving of space.

We may now pass to a consideration of one or two test curves, taken in the small scale plant department of Messrs. Manlove Alliott and Co., Ltd., Nottingham. Fig. 25 shows a family of curves relating to spent lime suspensions of various strengths. The total discharge is plotted against time, each test being made with a frame 4 in. deep, at a constant air pressure of 70 lb. per square inch. Readings were taken every minute, and filtration continued till three constant ones were obtained. The law connecting time and flow is well illustrated. In the case of the weakest suspension this is $T = 1{\cdot}19Q^2 + 0{\cdot}8Q$ (or $T = 3{\cdot}57Q^2/2N + 0{\cdot}8Q$) where T is in minutes. The effect of the consolidation period is shown by the difference between the upper part of the actual curve, and the dotted line representing the theoretical one. The maximum reading in gallons for each case is, of course, proportional to N, and on reference to equation (4) we see that the time to get a cake should also be proportional. If this holds, all the curves should end on the same straight line passing through the origin. The four tests with stronger suspensions agree well with this, except that the line is displaced a little to the right. This is no doubt due to some residual consolidation effect. The curves for the weaker suspensions vary markedly from this line, taking longer in proportion. On inspection the cakes were distinctly dryer in appearance, and the percentage moisture was found to be slightly less. Apparently the slower filtration was due to the fact that the lime particles had time to settle down more compactly; and it is probable that the smaller ones were gradually washed from between the larger (*cf.* Fig. 28) to form a more compact and impervious layer near the cloth. The distinction between the two rates of flow is very marked, but further trials would probably show that they merge more or less gradually.

Fig. 26 shows a time discharge curve for a sample of Direct Yellow recently tested by the writer. In this case a complete 1 in. cake was formed at a very early stage, though, of course, it was extremely soft. This was tested and confirmed by two separate trials, at the end of which the press was opened while still draining freely. The curve itself is the result of a third trial carried on as long as seemed worth while. In this case, although the conditions under which the solids are deposited are so very different from the former instance, the curve agrees well with $T=115{\cdot}4Q^2+25Q$ (or $T=255Q^2/2N+25Q$) right up to about 80% of its total flow. Curiously enough, where it departs from the formula, the curve shows a quicker rate of filtration, and this divergence may be due to some slight subsidence of the suspended solid matter, so that during the latter portion a comparatively weak liquor might have been fed to the press. The mixture was, however, kept agitated during the whole test.

On the same chart has been plotted a curve showing the rate of filtration, at every moment during the test, as compared with the horizontal line giving the average rate of flow over the whole period. Nearly half of the substance is fed in at a considerably higher rate than the average, while it will be seen how slowly the flow from the taps comes to an end as the cake is gradually consolidated.

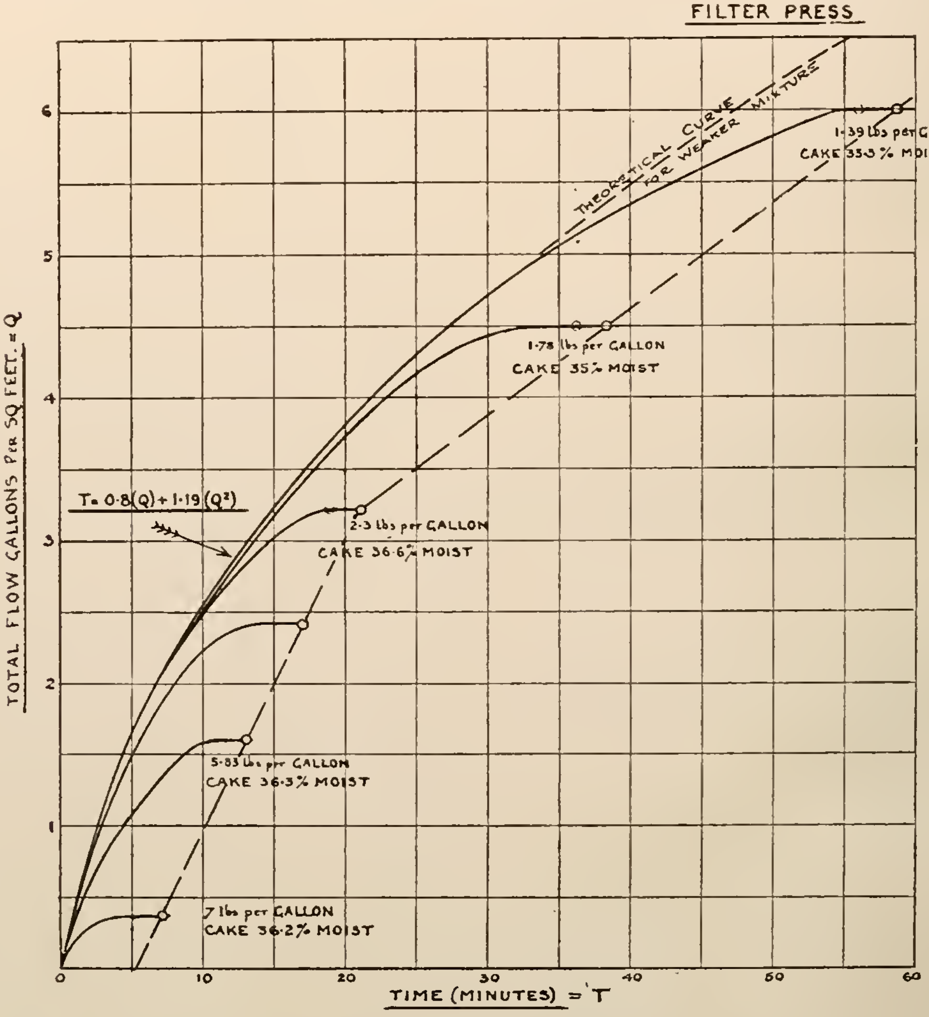


Fig. 25.

Filtration of caustic liquor containing various amounts of spent lime. 4-in. cakes, 70 lb. air pressure.

The tests on both the lime and the dye were made with the same cloth, and exhibit clearly how different are the resistances of the cakes, and how markedly the resistance of the cloth varies when the latter is used under altered conditions.

The permeability and dryness of a filter cake depend on the size and shape of the particles, and especially on their texture, whether firm or otherwise. Comparatively coarse, hard grains are favourable, as the capilliary passages are large, and high pressure can be used. It is not, however, desirable that the grain should be so coarse as to cause rapid settling. If this should happen in the press a cake of uneven quality would be formed, which would be unfavourable for washing or air drying. It might be difficult also to secure a clear effluent, as is explained later.

A great part of the art of filtration lies in the control of the nature of the suspension. In this the microscope is a useful aid. Higher powers than $\frac{1}{6}$ in. objective, and 9 times eyepiece are not usually necessary, but for substances like anthracene or β-naphthol a polariscope is useful in rendering the crystals visible. If the particles are mounted in liquor they can be made to separate or turn over by pressing with a sharp point on the cover glass, and thus their real shape and the compactness of their grouping may be judged. By this method, for instance, it can be seen quite clearly that β-naphthol particles consist of large, though very thin, flat plates, while particles of anthracene in

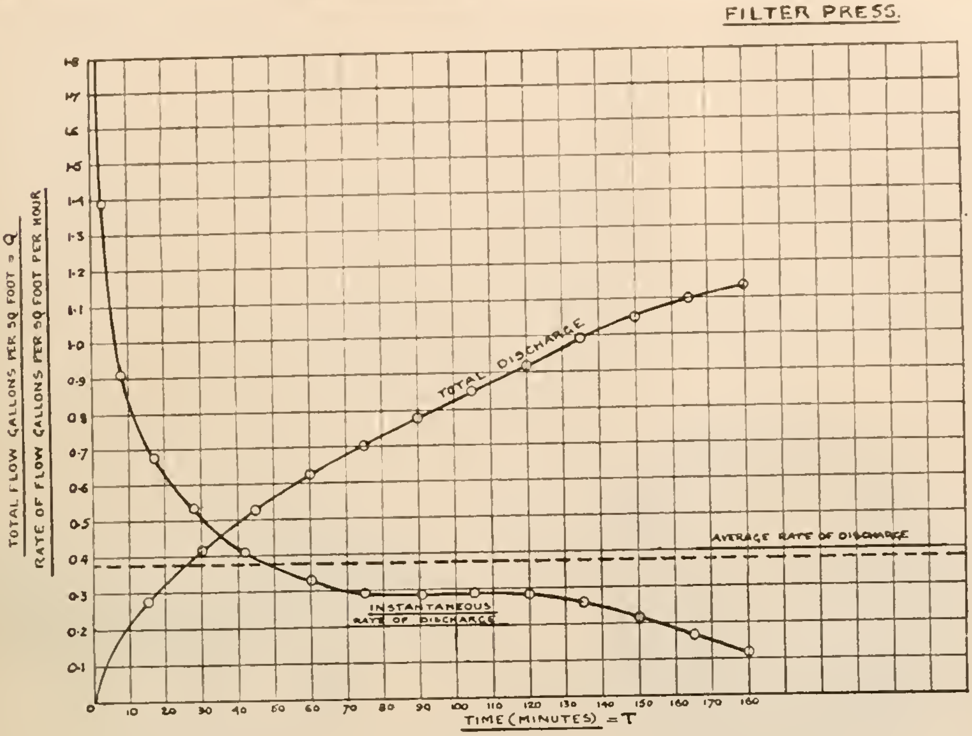


Fig. 26.

Time discharge curves for Direct Yellow.

suspension in oil, having very much the same appearance while still, are really somewhat irregular nodules which are more or less of equal shape when viewed from any angle.

Fig. 27 shows the previous sample of calcium sulphate magnified to 250 diameters. It will at once be seen what a coarse open meshwork will be built up in the cake. Such a shape and size of crystal is, of course, extremely free filtering, and is very favourable to good washing results. The needles shown run 0·001 in. in length, or even larger, and the breadth is about 0·0001 in.

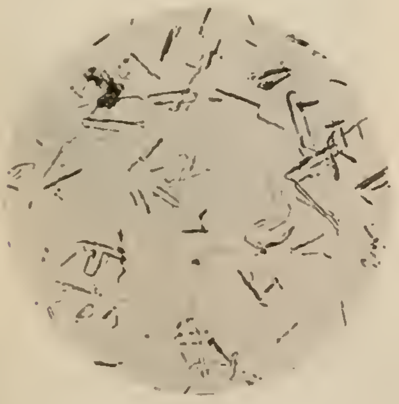


Fig. 27.

Sulphate of lime (×250).

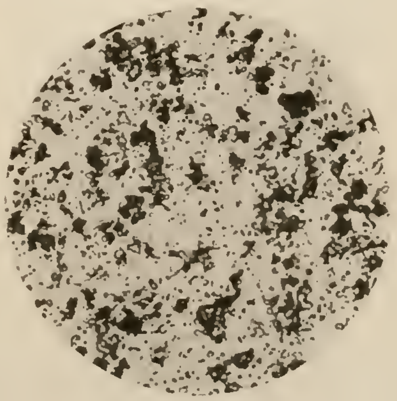


Fig. 28.

Spent lime (×250).

Fig. 28 shows on the same scale a suspension of calcium carbonate. Many of the crystals have aggregated to form comparatively large firm lumps, but the scattered particles will give a fairly good idea of the size and shape of the individual unit. Numbers of these are only 0·0001 in. in diameter, while some are even less. This material is, however, quite free filtering, as will have been gathered already. This is due to the fact that the particles are hard and angular, with no trace of sliminess or gummy matter, and the aggregated clusters are sufficiently firm and numerous to keep the cake open. The precipitate from soap lye presents quite a different appearance (fig. 29). Even in the photograph the shapeless outline and scummy nature of the particles are indicated, suggesting good results would be secured by not too high pressures. Fairly rapid filtration may, nevertheless, be obtained, and probably this is due to the comparatively large size of the particles concerned. A somewhat different appearance is presented by the various aniline dyes. In the case of the substances previously mentioned, all the particles appear to be at rest, but in the case of dyestuffs a number are often to be seen in motion. If, for instance, Benzopurpurine is examined in suspension in water, assuming the preparation has been freshly made up or recently agitated, each particle would seem to be separate, assuming a thread-like form 0·0002—0·0001 in. long by about one-tenth of this in diameter. Some preparations are even smaller, while the Brownian movement is very distinct. After a long period of rest all movement will have temporarily subsided and the separate particles will have massed themselves together in such a manner as shown in Fig. 30. Filtration at comparatively low pressures is clearly indicated.

The agglomerated and motionless condition is the more favourable to good working. The particles may also be seen to be of somewhat larger dimensions than when they are scattered and freely moving. Since this state can be brought about by the presence of an electrolyte such as salt, it is good to retain a suitable proportion of this if market conditions, etc., will permit. Naturally cake formation is apt to be slow at best with deposits of this type, and closely woven cloths are necessary. Washing is usually out of the question. This is partly due to the high resistance of the cake, and to the fact that as soon as water penetrates the mass it removes any electrolyte present, and the dye particles then assume a still more intractable nature.

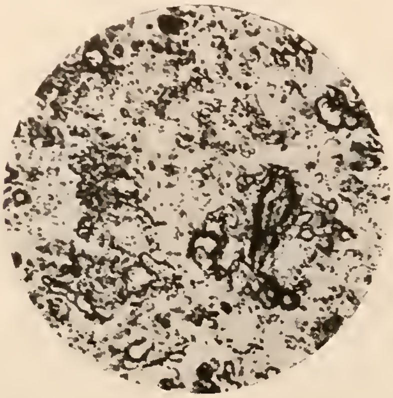


Fig. 29.
Sludge from soap lye (×250).

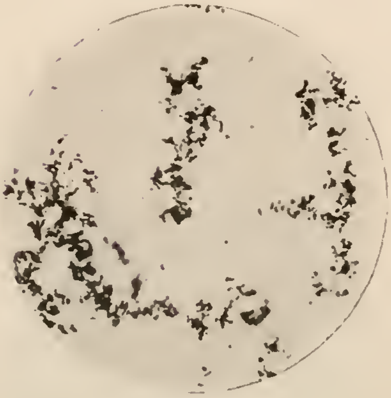


Fig. 30.
Benzopurpurine (×250).

Fig. 31 shows a sample of Direct Yellow. This gives a freer flow and is more readily retained by the cloth, as is indicated by the large size of the particles and the way in which they are massed. Fig. 32 shows a sample of filter paper on the same scale for comparison.

Before leaving the subject of quality of grain, it may be of interest to mention a curious property of many filter cakes (due to the shape and hardness of the particles. Such cakes appear firm and comparatively dry and free from surface moisture when first discharged. If a small piece is shaken in the hand it becomes sloppy, and a distinct amount of free surface moisture appears. This is due to the fact that the particles are deposited initially in any order, but when shaken assume their most compact grouping, causing the moisture in the interstices to appear at the surface. Further, as was shown by Osborne Reynolds (Scient. Papers Nos. 50—51), such hard material does not necessarily assume its most compact grouping under the application of pressure, providing this is not sufficient to crush the grain. This supposes the existence of an elastic boundary, which is provided by the cloth. This property Reynolds termed "dilatancy" (Fig. 33). It is so marked that if a football bladder is filled with fine sand and water, and fitted with a glass tube in the neck, excess water will not be forced out, but is actually seen to be drawn into the bag when the latter is squeezed.

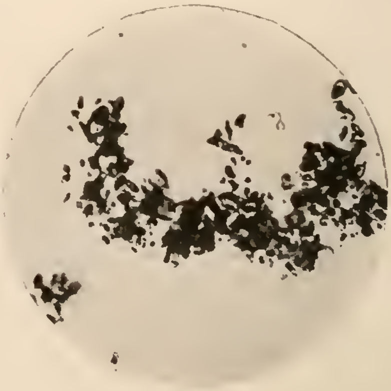


Fig. 31.
Direct Yellow (×250).

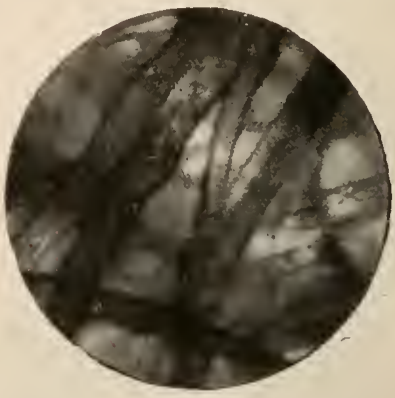


Fig. 32.
Grey filter paper (×250).

Some liquors contain particles so fine that they cannot be retained on the usual filter cloth, unless of a very close texture, while in other cases, such as sugar scums and some varnishes the liquor is so slimy that an impenetrable layer is speedily formed on the cloth and it becomes impervious. In such cases various aids to filtration can be used. The requirements for such an aid are as follows:—

(1) It must form a readily permeable deposit.

(2) It must not be difficult to keep in suspension.

(3) The capillary pores between the particles must be sufficiently fine.

(4) If very fine scummy particles are to be removed, it must have a maximum of surface, and its nature must be such as to favour adsorption.

(5) It must have no injurious action on the material being filtered.

Among such substances may be mentioned calcined fuller's earth, diatomite, and various other refined fossil earths, crystals of calcium sulphate, charcoal, wood meal, cotton meal, etc. In some cases it is possible to produce a lime precipitate in the liquor before filtering, with the result that the slimy particles are covered with a lime deposit and the cake rendered more open and permeable.

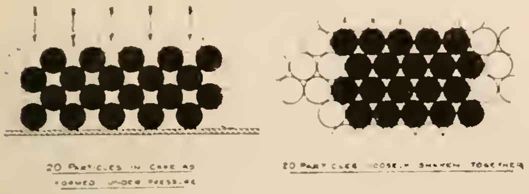

20 PARTICLES IN CAKE AS FORMED UNDER PRESSURE
20 PARTICLES LOOSELY SHAKEN TOGETHER

Fig. 33.

In this connexion it should not be overlooked that the coarser particles in a precipitate may assume the nature of a filter aid towards the smaller ones, which would not be retained by the cloth if the whole precipitate were fine. Hence it may be difficult to get clear filtrates if the larger particles are given time to settle out in the filter press owing to insufficient pump capacity, etc.

For fine clarification the cloth may be given a very thin coat of the filter aid by pumping in a suspension of the latter before commencing to filter. It is also useful when mixed with the liquor, as it not only helps to give a clear filtrate, but builds up an open structure in the cake, thus permitting a more rapid flow where slimy matter has to be removed.

The following weights of dry solids per cubic foot of press capacity—together with the moisture in the cake—may be of interest. They are all taken from ordinary large scale practice. They should, however, be regarded only as a guide, as very different results are sometimes obtained between one factory and another. Those moistures marked with a * have been reduced by means of blowing air through the press:—

Material.	Dry weight per cb. ft.	Moisture, % on wet cake.
Orange chrome	340	* 5
Zinc chrome	200	* 7
Lemon yellow chrome	46	55
Para Red	53	30
Prussian blue	15	60
Magenta lake	20	60
Wolfram tin fines	136–160	10–17
Tungstic oxide	104	14–21
Spent lime	57	38
Calcium sulphate	42–55	40
Anthracene	29	46
β-Naphthol	47	* 30–40
Sulphur black	42	* 40
Sulphur blue	59	* 32
Wool red	19	* 60
Direct brown	35	* 50
Benzopurpurine	38	* 35–40
Congo red	42	* 50
Triacid violet	23	* 30–35
Orange II	20	* 40–45
Potter's clay†	96	20
Sewage sludge	30	60
Sludge from soap lye	30	60
Yeast	56–64‡	75

† Different mixings vary somewhat.

‡ The weight given for yeast cake covers about 72½% combined water.

Cake thicknesses vary from ⅝ in. up to 4 in. or even 6 in. in the case of very permeable deposits. Some samples of calcium sulphate and carbonate will build up to the higher figures. In many cases 2 in. is considered a good thickness, even for the above substances. Colours and dyestuffs are usually filtered in presses having chambers 1 in. to 1¼ in. thick. Materials are not unknown which will build a layer only a few hundredths of an inch in depth. In such cases cake formation is impossible, and the excess liquor has to be drained out of the press.

It is well worth while for users to study and test the best pressures for feeding their particular grade of material. Too many operators are satisfied that things are right so long as a clear effluent is obtained, and it is not realised that better results are often obtained by relatively low pressures, except perhaps in the last stages of the run. In relatively few cases does high pressure produce proportionate results either in rate of flow or weight and moisture of filter cake. In fact, it may reduce the rate of flow or stop it altogether by destroying the open structure of the deposit.

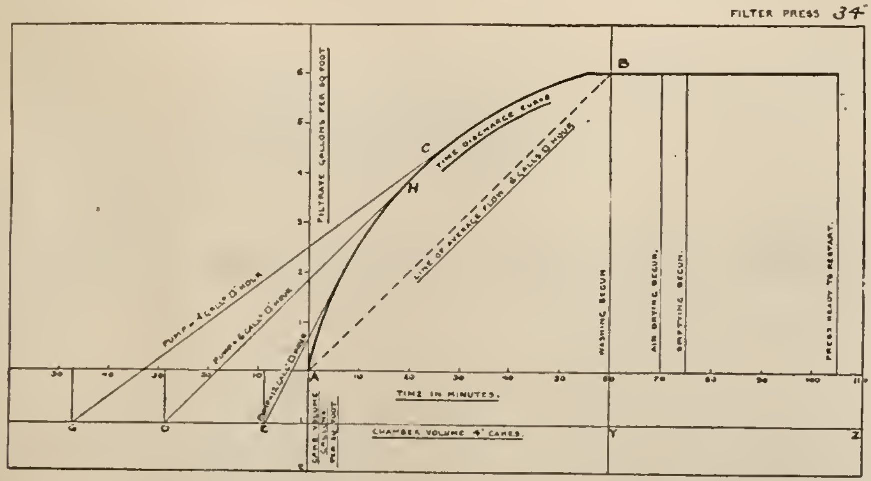


Fig. 34.

Correction of time discharge curve for cake volume and pump capacity. Rapid filtration.

In ordinary filter press work pressures may range from, say, 150 lb. per sq. in. down to 20 ft. gravity head or even less. The higher pressures are only suitable for very viscous liquors containing hard solids of an open granular nature. When viscosity is small pressures of 70 to 100 lb. are usually ample for granular or fibrous suspensions, while many materials of only a tolerably open texture are dealt with very satisfactorily at 40 to 60 lb. Dyestuffs, colours, etc., and other materials of a very fine nature are often advantageously handled at half this pressure or even less. Prussian blue, for instance, is generally dealt with at 30 ft. gravity head.

Even when higher pressures are justifiable it is well to start the operation at a comparatively low pressure in order that the first layer of the cake may be open and porous. For slimy materials the preliminary feed may well be under a low gravity head. Once a good layer has been formed there is a tendenecy for the particles to interlock, and they are then less liable to be forced through the cloths by a higher finishing pressure.

Rates of filtration are very varied. They are highest where large quantities of liquor containing small amounts of solids are being handled, providing that it is not necessary to form a cake of high solidity. In such cases it pays to clean the press out as soon as the rate of flow falls off In clearing a watery liquor from impurities and dirt, rates of from 15 to 30 galls. per sq. ft. per hour are often obtainable. On the other hand, viscous materials, such as varnish, may only give a flow of $\frac{1}{3}$ gall. per sq. ft. per hour, but vegetable oils have rates of flow varying from 4 to 8 galls. per sq. ft. per hour, but in other cases these figures may be halved. In one case soap lye after acidification filtered at the rate of 4 galls. per sq. ft. per hour, and the same liquor after neutralisation gave a flow of about double this amount. This filtration was carried out at a pressure of about 20 lb. per sq. in., never exceeding 30 lb., whereas it is sometimes considered that pressures of 100—150 lb. are necessary for this material. In another case the lye was filtered only after neutralisation, and the rate of flow was $5\frac{1}{2}$ galls. per sq. ft. per hour under a gravity head of only 20 ft.

In the case of sewage, rates will vary from 3 galls. down to $\frac{3}{4}$ gall. per sq. ft. per hour, the usual figure being about $1\frac{1}{2}$, and the pressure 80—100 lb. per sq. in. For the majority of dyestuffs the range is about 2 galls. per sq. ft. per hour down to $\frac{1}{5}$ gall., and in very difficult cases one gets down to a flow as little as one-tenth of the latter amount.

Methods of Feeding the Press.

Fig. 34 illustrates one method of fixing a suitable pump capacity. A time-discharge curve, ACB, is obtained in the usual way, the dotted line, AB, representing the average discharge. It is presumed that the original curve is obtained experimentally from a small-scale test, in which case the rate of flow is generally determined entirely by the press and not by the pump. It is further assumed that the substance is one in which it is permissible to use pressures rapidly approaching the maximum in the early stages of the test. A curve obtained in this manner needs to be corrected for the volume of the cake itself and for the employment of a pump of a practical size. In the instance given, AB corresponds to the steady discharge of a pump having a capacity of 6 galls. per hour per sq. ft. of filter area. The volume of cake is 1·04 galls. per sq. ft., and a line GZ is drawn to represent this at a suitable distance below the horizontal axis. The line DH is parallel to AB and tangential to the discharge curve. It represents the steady flow of the pump, pumping up to the maximum pressure at which the relief valve is set, which is reached at point H. The distance of D from the vertical axis represents the extra time per operation when a pump of this capacity is employed. The position of the point E gives a similar figure for a pump of double this capacity, and G for a rather smaller one. The times for washing, air-drying and emptying the press have also been added to the chart, and this enables a reasonable judgment to be made as to what correction should be allowed for the pump. On rates of filtration thus obtained the most economical size of press and pump may be calculated, due attention being given to the effect of any variation in the size of press on the emptying period.

Such a diagram is useful in so far as it gives a clearer perception of the various problems which enter into the determination of pump capacity and total output. In some cases, where filtration is free almost up to the last moment, and the pump

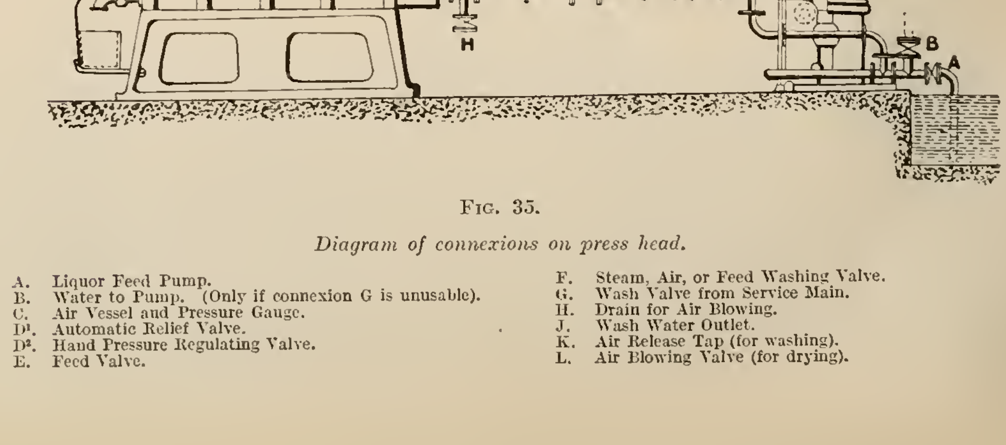


Fig. 35.

Diagram of connexions on press head.

A. Liquor Feed Pump.
B. Water to Pump. (Only if connexion G is unusable).
C. Air Vessel and Pressure Gauge.
D¹. Automatic Relief Valve.
D². Hand Pressure Regulating Valve.
E. Feed Valve.
F. Steam, Air, or Feed Washing Valve.
G. Wash Valve from Service Main.
H. Drain for Air Blowing.
J. Wash Water Outlet.
K. Air Release Tap (for washing).
L. Air Blowing Valve (for drying).

is not too large, it is possible to force the liquid through at the full capacity of the pump during the whole filtration period, thus avoiding waste flow through the relief valve. This generally entails somewhat slower filtration than might otherwise be obtained.

Fig. 35 shows the full connexions of a thorough washing filter press fed by a vertical plunger pump. It will be noticed that the air vessel is much larger than usual in order to minimise pressure fluctuations. In filtering pressure sensitive materials with a single-acting pump this point should not be overlooked. A pressure gauge is desirable, as it enables the operator to see whether the pump is working properly and the pressure is being put on at a suitable rate. An automatic relief valve, set at the maximum pressure, is placed on the pipe between pump and press, and the liquor from this returns into the pump feed connexion. A re-circulating valve, worked by hand, is sometimes provided so that the first layer can be placed comparatively slowly on the cloths. Connexions are also shown for pumping wash water into the press, and in this case it is necessary to flush the pump and connecting pipes before washing. It is preferable, however, to have separate arrangements for the water supply, as the best pressure for washing is not as a rule the pressure at which the liquor should be fed to the press. Generally speaking, more than enough pressure will be got from the water main or even from an overhead tank. In practice dead lengths of pipe between the press and any of the valves are to be avoided and the pressure relief valve is best brought up near to the feed valve where possible to avoid clogging or settlement in the feed pipe during the final consolidation period.

In addition to the pump connexions, steaming valves have been indicated both on the feed inlet and wash water outlet passages together with an air connexion for blowing air into the cake and a drain connexion on the bottom passage to serve as an outlet for any liquor blown off by this means.

The diaphragm type of pump (Fig. 36) is a very good method of dealing with thick sludges and is also useful for acid liquors, as it lends itself to coating with lead or vulcanite or other materials on all parts except the rubber diaphragm.

A single-acting pump is often a necessity for small duties, but it is really the worst type, as even with a large air vessel pressures are apt to be fluctuating. For larger duties double-acting, or better still, treble-acting pumps, are desirable. Special pumps are also constructed in such a way that the effective stroke is decreased with increasing pressure, thus diminishing the rate of flow and causing the pressure to be put on gradually. The duplex steam-driven type of pump is a good pattern, as it gives a reasonably even feed and is to a large extent self-adjusting to meet increasing pressure. Even this type is generally fitted with a relief valve and large air vessel. The ram should be of the outside packed pattern where packings are likely to require frequent attention.

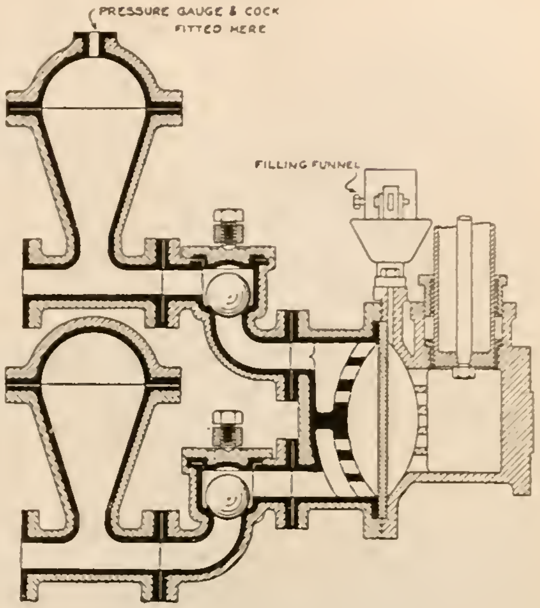


Fig. 36.

Sectional arrangement of vertical diaphragm pump.

Undoubtedly the best way of charging the press, where gravity feed is not applicable, is to use an egg and force the slurry in by compressed air.

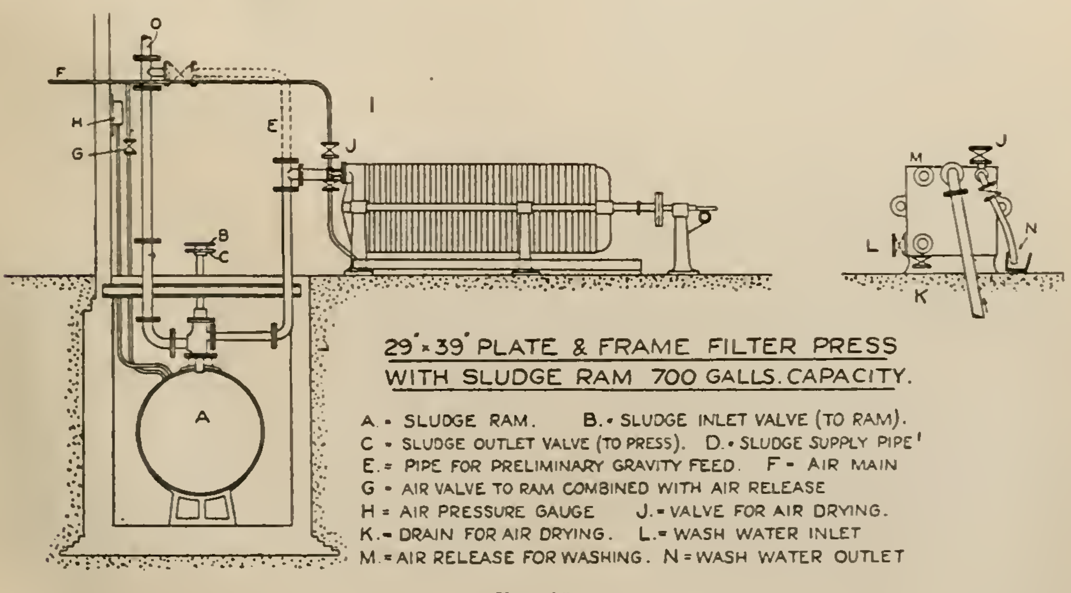

O
F
H
G
E
I
J
B
C
A
M
J
N
L
K
29"×39" PLATE & FRAME FILTER PRESS
WITH SLUDGE RAM 700 GALLS. CAPACITY.
A.= SLUDGE RAM. B.= SLUDGE INLET VALVE (TO RAM).
C = SLUDGE OUTLET VALVE (TO PRESS). D.= SLUDGE SUPPLY PIPE
E.= PIPE FOR PRELIMINARY GRAVITY FEED. F = AIR MAIN
G = AIR VALVE TO RAM COMBINED WITH AIR RELEASE
H = AIR PRESSURE GAUGE J.= VALVE FOR AIR DRYING.
K.= DRAIN FOR AIR DRYING. L.= WASH WATER INLET
M.= AIR RELEASE FOR WASHING. N = WASH WATER OUTLET

Fig. 37.

Unfortunately this method is expensive except where a large number of presses have to be supplied or duties are large. Valve troubles are avoided, the flow adjusts itself automatically, and the pressure is perfectly even. On starting to filter the full initial flow is obtained at low pressure with a minimum amount of air. If several batches are necessary to fill the press it is only the latter ones which need air at the maximum pressure.

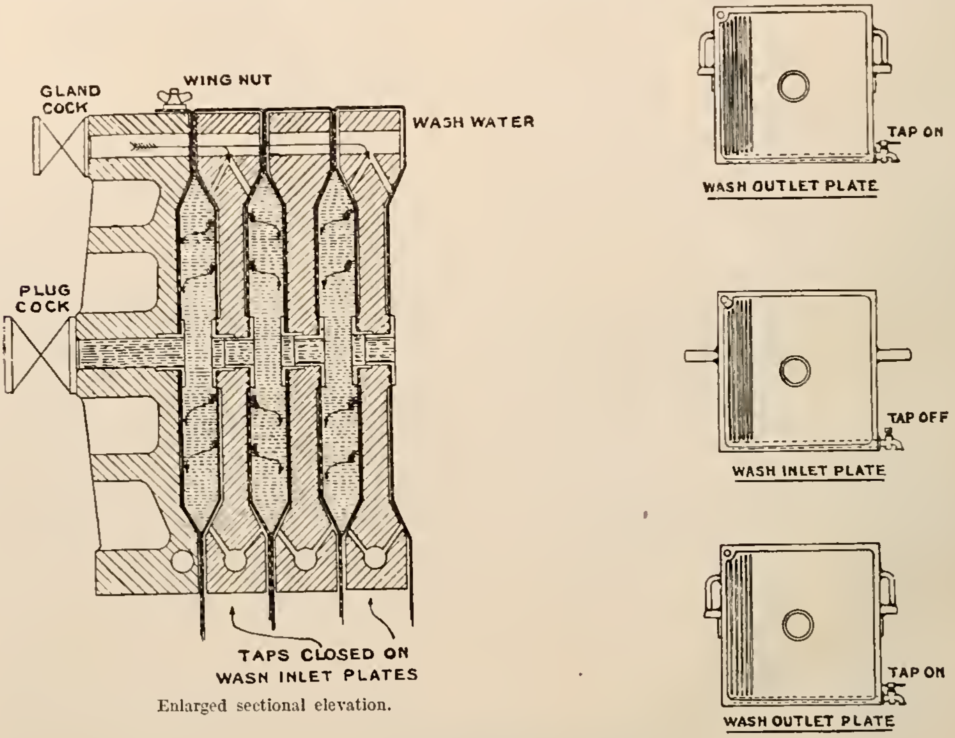
Fig. 37 shows a wood press fed by a ram situated in a chamber below the floor. The feed pipe from the supply tank on the upper floor has a connexion to the press for initial filling by gravity, thus economising air. For heavy sludges the air inlet pipe may be taken to the bottom in order to give a stirring effect, though for very heavy precipitates an agitating gear should be fitted. Rapid filtration in early stages is very valuable in the case of materials having a strong tendency to settlement, and in such cases where the grains are not uniform it will be found best to instal a large egg or receiver, in which the whole batch can be thoroughly stirred up and forced rapidly into the press. This method will give a more uniform and permeable cake than would be formed by a pump, more especially as most users are averse to paying for a pump sufficiently big to take care of the full capacity of their press during the earlier stages. This is an important point to consider when the best washing results are desired.

In a case which recently came under the writer's notice feeding with a small pump gave cake which could not be washed below 2% soluble matter with any amount of time or wash water, but when a ram with agitating gear was installed the cake could be washed to under 0·2% with but little trouble.

Washing in the Filter Press.

Washing can be carried out with great advantage in the filter press. The simplest method is to force water in through the feed passage. This is best done in the plate and frame type, and it is preferable that a solid cake should not be formed, but that a space should be left between the layers built up on each cloth. Here a bottom feed is advantageous, as the excess liquor can be drained from the chambers prior to washing, though in the ordinary type it can generally be removed by air pressure. It is possible to wash this way in any plate and frame press or even in recessed presses, although they may not have been specially designed for the purpose. If a solid cake is not formed it is the only practicable way except re-lixiviation.

The trouble is that owing to sedimentation the cake is apt to be thicker at the bottom, and in order to keep the two sides from touching space may be wasted at the top. Further, the press capacity is diminished and more labour is necessary in emptying. In some cases, however, solid cakes can be rough washed if they are sufficiently permeable. General reports from users appear to show that more wash water is requisite, but this would depend very much upon the manner of the operation. This method of washing is usually referred to as "simple" washing. Another consists in forcing the water from one side of the cake to the other, and may be referred to as "through" washing. It is also called "back" washing, as the water is admitted to the back of the cloths.

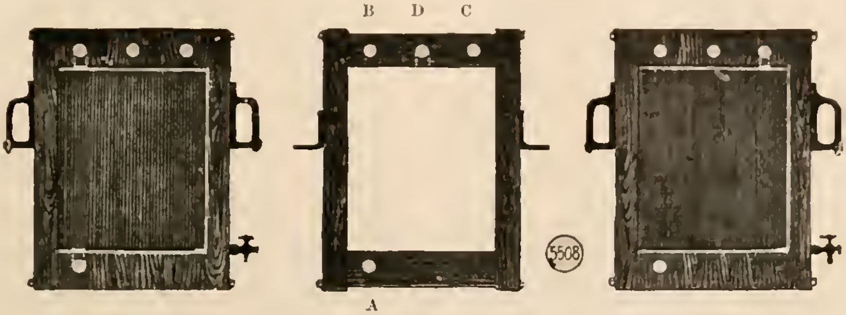


Enlarged sectional elevation.

FIG. 38.

Recessed plates. Washing type.

Fig. 38 shows this method applied to recessed plates. The wash water inlet passage forms a continuous channel in an upper corner of the rims. It has inlet ports to each alternate plate, on which the filtrate cocks must be closed during washing. The water enters behind the cloths, passes through these and the cakes to the back of the cloths on the intermediate plates, the cocks on which have been left open to permit it to escape. This is sometimes called "tap washing," and its chief merit is its simplicity, as only one special passage is required. One disadvantage of an internal feed is that a soft core will permit shortcircuiting, while a hard one may not get washed properly. For the very best results plate and frame presses should be employed, owing to the even thickness at the cake at the edges and the fact that any soft material in the feed passage is isolated. Further, provision should be made for the escape of any air which may have leaked into the space behind the filter cloths at the conclusion of filtration, as this may prevent the water flowing through the upper portions of the cakes. Even ordinary "tap washing" is distinctly improved by the provision of air cocks. Then, again, the washings should be taken out at the top of the press, so that there is exactly the same pressure tending to force the water through the cake whether this be measured at the top or at the bottom. The importance of these factors will be better understood when it is realised that comparatively low pressures are best for washing purposes, as will be seen later. Except where due provision has been made, time will be required under such conditions to force trapped air out of the press, and in addition any unbalanced hydrostatic head (due to unrestricted draining on the outlet plates) will aid in causing a disproportionate amount of wash water to percolate through the bottom of the cakes.



A = Wash water inlet.
C = Wash water outlet.
B = Air release.
D = Feed channel.

Fig. 39.

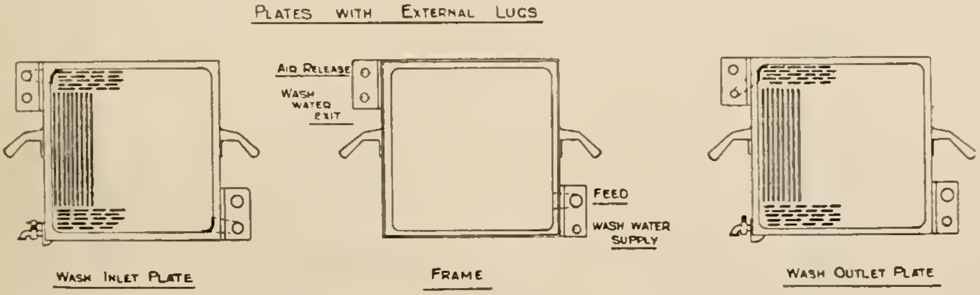


Fig. 40.

A filter press in which all these points have had attention may properly be described as a "thorough" washing press (Fig. 39). The illustration shows wood plates and frames constructed on this system. At the conclusion of pressing all the filtrate taps are shut off and wash water is admitted to the enclosed channel at the bottom. This passage connects by ports to every alternate plate and permits the water to rise behind the cloths on these, driving the air before it into the special air channel which connects with the wash inlet plates only. As soon as there is any flow from this it is shut off, and the water must then pass horizontally through the cakes and cloths to the intermediate plates, where it rises in the grooves till it escapes into the enclosed outlet at the top. In this way provision is made for as perfect a displacement as possible of the strong liquors in the cake. An even better arrangement would be to have wash outlet cocks fitted on the tops of the plates, delivering into a special trough, as this would permit any chamber giving muddy washings to be shut off at will. In general practice, however, enclosed outlets are found more convenient and perfectly satisfactory.

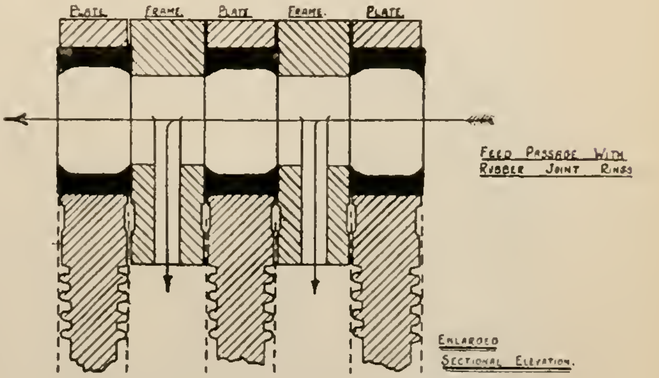


Plate
Frame
Plate
Frame
Plate
Feed Passage With Rubber Joint Rings
Enlarged Sectional Elevation

Fig. 41.

An interesting point about presses of this type is their extreme adaptability. There are a dozen possible variations of the washing connexions alone, since any passage can be used as an inlet, without counting possibilities in regard to steaming, air-drying, etc. The chief methods of washing are, however, ordinary thorough washing as above; washing in reverse direction, either through the enclosed outlets or through the taps and ordinary simple washing as first described. The wash water and air passages can be used as enclosed filtrate outlets. It is obvious that air, steam, or water may be admitted to the wash passages when the press is empty, but closed up ready to restart. By this means the cloths are given a reverse washing, and may be made to last longer before clogging.

In the case of iron plates, these wash passages are made either in the plate rims or can be in external lugs (Fig. 40), with advantage in certain cases, since this permits plain cloths without holes to be used, and there is no difficulty in fitting and keeping them in place. The joints on the lugs are often made by cloth sleeves, which are slipped over them. These must be changed with the cloth, and for that reason rubber joint rings are often preferred. These may be let into special grooves around the wash passages, or may fit inside as shown in Fig. 41. Hydraulic lipped rings are shown, but quite good results may be obtained with plain rings, which should be just a push fit inside the channels. Rubber is not always permissible, and a more expensive press is required than if cloth sleeves are used.

In any event the cost of outside lugs is only justified where the filtering medium is subject to frequent washings or renewals. Normally the cloth is kept in place by adherence to the plates once it has been used, so that even where passages are in the rims no difficulty is experienced in keeping the holes in their right positions. If the cloths last a reasonable time and proper arrangements are made for cutting the port holes, the cost of this is small in proportion to the work done. A useful type of plate has two external passages in lugs which form part of the handles (see Fig. 42). One of these is a feed passage, the other the wash water inlet passage. This form permits the outside lug plate to be made more cheaply, in a form very convenient for manipulation, but lacking some of the advantages of the type shown in Fig. 40.

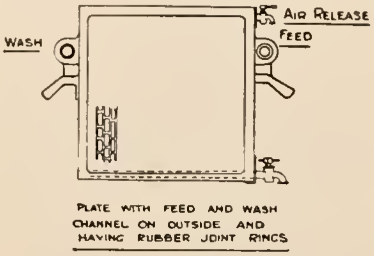

AIR RELEASE
FEED
WASH
PLATE WITH FEED AND WASH CHANNEL ON OUTSIDE AND HAVING RUBBER JOINT RINGS

FIG. 42.

Now, assuming that a press has been selected with all facilities for washing, as described above, and care has been taken that the filtering surface has been kept free and unchoked, giving the wash water access to every part of the cake, there are still other factors essential to satisfactory results. These are:—

(1) Care must be taken to secure a well-formed cake.

(2) The cake must be of as coarse a grain as is possible, without causing settlement in the press, and the various grades of particle must be uniformly distributed.

(3) The washing pressure must not be too high and should not fluctuate. It should be applied as quickly as possible after the cake has been formed.

(4) Care must be taken that the press is worked properly and especially that the air-taps are made use of.

Economical washing depends on even displacement, and good practice results when this ideal is approached as nearly as possible. If the cake is not complete, obviously there will be gaps, through which water can pass. Further, if the deposit is soft and not properly compacted such gaps may readily be formed during washing, while if this operation is delayed some cakes tend to sag a little and do not fill the chamber up to the top. The frames may be fitted with an internal rib or fin to counteract the effect of this, but some users consider there is more difficulty in cleaning out the cake. Then if the grain is too fine it will be difficult to get the wash water to penetrate without undue pressure, which may cause channelling and short circuiting. In such cases adsorption effects are also likely to hold back soluble matter in spite of even the most perfect washing. If the grains are reasonably coarse they will be more permeable, and will have less surface to retain strong liquor. A truer and quicker displacement is then likely to result. If they are not of fairly uniform size, the coarser ones will probably have settled to the bottom of the chamber, and the wash water will pass in preference through them, giving mixed or weak washing. If the particles themselves are porous, time will be needed to extract the absorbed soluble matter, quite apart from surface effects.

Finally, high pressures should only be applied with caution where absolutely necessary, as these may cause channelling and short circuiting. The lowest which will give a reasonable flow should therefore be used. The supply must be steady, and a gravity feed or a connexion to the town water supply is usually preferable to the use of a pump, where either can be employed. While the best results are usually obtained at pressures much less than those in general use for consolidating the cake, it should not be overlooked that the filtrate has only to penetrate half of its thickness, while the wash water must pass through the whole depth of the consolidated mass. In order that washing may not be too prolonged, the best cake thickness is usually somewhat less than for plain filtration. Good supervision is necessary, as one often sees presses provided with all the appurtenances for scientific washing being handled in a most unintelligent fashion. The author has seen thorough washing presses with practically every valve and tap open except the air cocks, while wash water was being admitted behind the cakes

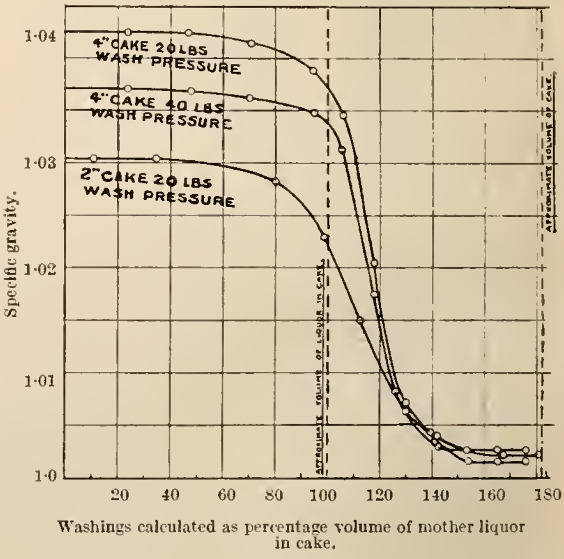


FIG. 43.

and into the feed passage at the same time. Needless to say, in such an instance every ounce of pressure that could be go out of the mains or wash pump would be applied.

Fig. 43 shows some tests carried out by the author on the washing of very weak caustic solutions from spent lime cake. It will have been realised from the photomicrographs that many of the particles in such a cake are extremely small, and consequently there is plenty of surface to hold back traces of alkali. Nevertheless, in these experiments almost theoretical results were obtained, the strength of the washings keeping right up to or quite close to the original strength till a volume equal to that of the liquor in the cake had been displaced. It will be observed there is still a fair strength of washings coming off even after this point has been reached, this being doubtless due to residual liquor behind the cloths and in various passages immediately connecting with the press. Adsorption, and possibly capillary effects in the case of the clusters, doubtless play their part. The tests were made with a 4-in. cake at 20 and 40 lb. per sq. in. and a 2-in. cake with 20 lb. per sq. in. respectively. Not a great deal of difference is observable in the form of the curves. They all fall practically down to the specific gravity of the pure wash water after an amount equal to the total volume of the cake has been employed.

Washing weak caustic soda solutions from carbonate of lime cake (experimental).

Of course such results can hardly obtain in large-scale presses unless a good deal more care than usual is observed. In dealing with carbonate of lime one firm reports the use of about 1⅓ volumes of wash water (compared with cake volume) at 15 lb. pressure to wash cakes 1¾ in. thick and 24 in. square, the residual free alkali in the cake being 0·2 or slightly under on a fair average of the cake. The time for washing was about ten minutes. In another case sulphate of lime cakes 2 in. thick were washed free from all but a trace of a certain organic salt with 1¼ volumes of washings. In dealing with gold slimes cakes of practically pure silica about 36 in. square by 1 in. to 1½ in. were washed free of cyanide solution with about 2½ volumes of water compared with the volume of liquor in the cake. Sugar scums, filtered by the aid of kieselguhr or lime admixtures, would require about 1¼ to 1½ cake volumes.

If the deposit contains slimy or colloidal matter in any quantity, and the particles are fine, much more water in proportion will be required and the washing time will be protracted. Certain classes of dyestuffs cannot be washed for the reasons previously stated when discussing the photomicrograph of benzopurpurine (see page 18).

Fig. 44 shows the relation between strength of washings and time taken in freeing from soluble matter a carbonate of lime cake contaminated with colloidal silica, which tended to wash out on to the cloths and choke them. In this case it will be seen that to economise water washing has been carried out in three stages, one with a strong liquor, followed by a second wash with a weaker solution, and, thirdly, with pure water. The volume of washings in each case was about 1¼ to 1⅓ times the volume of the cake. In treating a difficult wolfram tin slime, from which the coarser particles had been separated, only the fines being taken to the press, a head of only 4 ft. of water was used for washing. One and a-half cake volumes of washings left 1% of soluble matter, 2¼ volumes left 0·16%, while 3 volumes left 0·08%, or occasionally only a trace. With an especially difficult sample consisting of practically pure MnO and FeO, somewhat over twice this amount of wash water was required, the residual soluble matter being 0·3%.

Temperature control; steaming; hot and cold presses; air drying etc.

Viscosity is an important factor, as the rate of flow varies in inverse ratio. Since small increases in temperature may reduce viscosity in much greater proportion, the wise user will not overlook this means of increasing output.

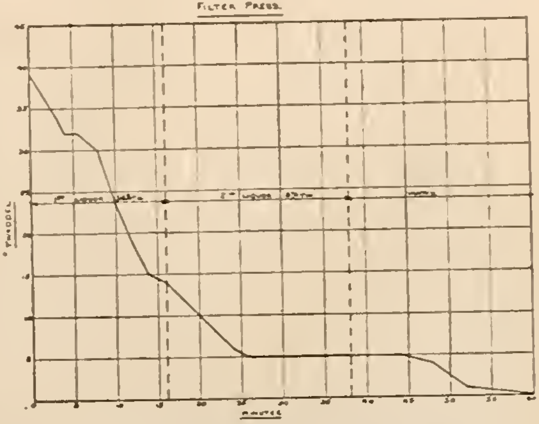


Fig. 44.

Washing carbonate of lime filter cake (contaminated with colloidal silica).

If the rate of flow is fairly large, the liquor itself will usually keep the press sufficiently hot. A steam valve is often fixed on the feed inlet, and this may be employed to pre-heat the press. It is also a very useful adjunct for steaming the cake and cloths through at intervals to keep them warm and render them more permeable, as in the case of wool grease recovery. In dealing with cakes of fuller's earth from the refining of lard, oils, etc., it is usual to steam these well through at the conclusion of filtration. This is best done one chamber at a time to concentrate the effect. After such treatment the cakes will usually drop out in the form of a loose meal, practically dry to the touch. They would then contain, say, 14% of lard, but reports are sometimes received of as little as 10% of grease remaining in the cake. Wool magma would retain about 20—25% of grease, but figures of under 16% are not infrequent.

Where filtration is slow, the press may require special heating arrangements, and Fig. 45 shows various types of plates which may be used. A very satisfactory form is to cast some simple passages in the plate to take steam at a few pounds pressure. The steam enters and the drain leaves by continuous passages similar to those used for washing. This is quite sufficient to keep the plates hot and counterbalance the loss of heat from the press. Alternatively a coil of pipe may be cast in the plates, but this is an expensive method and does not give any more satisfaction. Where the utmost application of heat is necessary the plates may be hollow throughout. (This construction is also very useful where liquors have to be kept cool while they pass through the press, as the greater area of directly cooled surface counteracts the somewhat low temperature head available for heat transference in such cases.) It is not desirable, however, to look upon the filter press as a heating battery; the devices just described are only intended to prevent the temperature of the liquid dropping (or rising) unduly.

In order to get drier cakes air may be blown through the feed passage or from one side of the cake to the other, using the wash passages, in which case it is better to take in the air at the top of the press and bring it out at the bottom, so as to allow of thorough draining. In the case of a permeable substance the moisture can be substantially reduced by this treatment in a very short time. In one case spent lime cakes were brought from 38% moisture down to 20% or 22% in about 4 minutes with air at 82° C. Air blowing is equally useful in the case of finer materials, but much more time is required. A pressing of β-naphthol was reduced from 60% moist to between 30% and 40% by 1 hour's treatment. Two hours is a not unusual allowance for dyestuffs, but occasionally it is considered worth while to continue for far longer periods. Where a separate air-supply is not available, the feed pump may be allowed to run for a longer or shorter period, sucking air and forcing it into the feed passage, a method which gives satisfactory results in many cases.

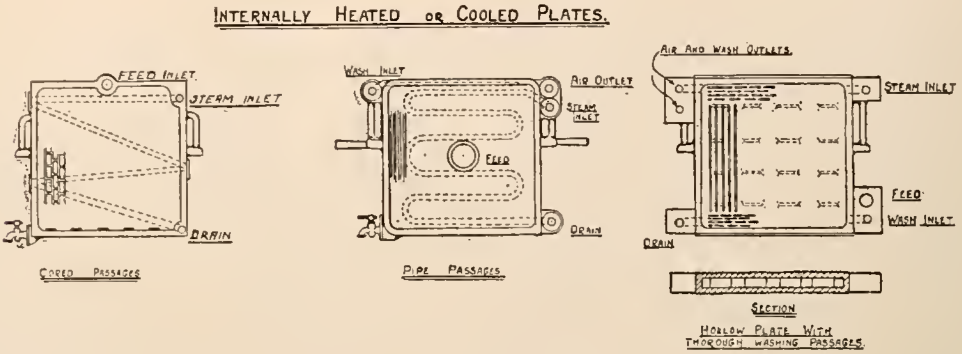


FIG. 45.

Discharging the filter press.

Labour costs are dependent upon the press itself, the general arrangement of the plant, the grade of material, and local conditions.

While small plates mean that a greater number have to be handled, very big ones are difficult to move rapidly and, generally speaking, medium sizes give the best results. Wood plates may be somewhat larger on account of their lightness. If the material drops away cleanly from the cloth, and especially if the plates are of the simple recessed type with central feed, then larger sizes may still be economical in labour, as discharging is then a simple matter. The question of the best number of chambers for high output has been discussed previously. It suffices to say that no great saving of labour is achieved in the case of long presses, as usually the time lost in attending to the closing gear, letting the press drain, etc., is a fairly insignificant portion of the discharging period. The 20 minutes per operation taken in the mathematical example was a very generous allowance. In most cases not more than 5, or at the most 10, minutes would be necessary, as will be judged from the examples to follow. Recessed plates require distinctly less handling than plates and frames, especially where no washing passages are required. Outside lugs do not make the difference one would expect, except where the cloths are frequently washed. There is also not much to choose among the various closing gears, so long as one is selected which will give efficient pressure. There is distinctly more to be saved by a proper arrangement of the press house, especially if it can be arranged for the operators to proceed directly from closing one press to opening another.

Reasonable room should be allowed all round each press, especially at the side on which the cake is to be brought away. It is helpful to have plenty of space below the press for dumping. Cake trays are distinctly labour economisers, but it is better where practicable to have the presses on an upper floor and discharge through shoots into trucks. Where this is impossible a useful plan is to have the tray or floor made sloping so that the discharged material can easily be raked down into a suitable receptacle. A good arrangement is to have the mixers, autoclaves or dryers which deal with the next operation so grouped with the presses that the discharged cake can be shovelled in direct. The pumps and sludge rams are preferably worked from the same platform as the filter presses, and the mixers which deliver the liquor to them should also be within easy access.

Most of the work depends, however, on the material itself, and the proper building of the cake. If the cake breaks up readily and drops cleanly away from the cloth, labour will be only perhaps one-half of what is necessary if the cake is half formed and sloppy, as then the whole cloth face must be thoroughly scraped. If such a partially built cake is of a clayey nature holding firmly together and binding to the cloth we have the worst conditions of all. Such clayey cakes, if properly built, may nevertheless fall away quite readily. Materials containing hard sandy grains require careful attention to the joint surfaces, or these may not come well together. Slimy substances also require more attention in careful cleaning of the cloth faces. If the liquor is such as to make the cloths tender, or if corrosive materials are being handled which might injure the hands of the operators, then again extra care and time are required. Then again, hard wash waters may give a deposit on the plate surfaces when washing out alkali, and labour in cleaning this off may be minimised by a proper attention to the water supply.

Low labour costs also depend on the proper choice of a cloth and the adaptation to filtration of the chemical and physical qualities of the material.

In order to eliminate the varying factors of thickness and weight per cubic foot of the cake it is useful to compare the number of man-hours per operation per 1000 sq. ft. of filter surface.

A 38-in. plate and frame press, with 50 chambers, dealing with tin slimes, took two men 2½ hours to discharge and get ready for restarting, giving a factor of 5·5. In the same establishment a wood plate and frame press, 40 in.×45½ in. externally, having 50 chambers, treating tungstic oxide, was dealt with by the same gang in 1¾ hours, the factor being 4·2. The operation of the closing gear took under 10 minutes. In both cases the presses were of the thorough washing type, and the cast-iron press did not have outside lugs. In another works a similar press, but 1 metre square, having outside lugs with rubber joint rings, took about 3 hours to discharge.

In yet another works a 36 in. square press, making thirty 1¼-in. cakes, with spur wheel and pinion closing, and feed and single wash passage in rim, took 2 men one hour to empty, giving a factor of about 4·2 man-hours. The cakes were dyes of a fairly soft, slimy nature. A press next to it working on the same product was 32 in. square with 40 chambers. It had toggle closing gear and outside ears for feed and wash-ports, and employed practically the same proportion of labour. The times for manipulating the closing gear took 3 minutes and 5 minutes in all for each operation respectively. The whole installation consisted of 6 presses, 3 of each kind, and employed two emptiers, one man shovelling cake from under the press into the mixing vessels, and one operating valves. The work proceeded on the three-shift system, and an additional man was employed during one shift to look after the cloths and keep the plate grooves free. As there were about 30 operations in 24 hours, the factor for the total labour worked out at about 7·15 on the average. In all the above instances unfavourable conditions might increase the time taken by 25% to 50%, while in the case of some dyestuffs the factor may be as large as 11 or 12.

As against this a 38-in. recess plate filter press with 50 chambers would certainly be dealt with in from 30 to 40 minutes all told when working on sewage, giving a factor of 1·48. These figures assume that the sludge is not in the most favourable condition for discharging, nor the labour of the very best. In dealing with Potter's clay about the same proportion of labour would be required, but the cake would have to be well pressed, and the men should preferably be paid on a piecework basis.

It is possible to obtain still better results, as, for instance, at the Dalmarnock Sewage Works. Through the courtesy of Thomas Melvin, Esq., it may be said that the installation consists of 19 presses, 12 of which have 40 chambers 40 in. square externally, the remainder having 34 chambers. Two labourers discharge from 36 to 37 pressings in an 8-hour shift, averaging one every 13 minutes throughout the day. This gives a factor of about 0·6. A timed operation on one of the shorter units showed that two men took well under 10 minutes, including replacing a cloth, giving a factor of 0·49. The total labour in this instance included in addition a working foreman who operated the valves, one man on the lime mixer and one looking after shoots and wagons. The total labour factor is thus 1·47, and in this instance supervision is included.

In another sewage works, using the very largest type of press, the factor for discharging works out at about 0·91, and the total labour factor 1·36 without including foremen.

Through the courtesy of Joseph Garfield, Esq., M.Inst.C.E., it is possible to give the following description of the sewer grease recovery plant at Esholt, Bradford. The installation contains 128 presses, making 47 cakes 36 in. square and 1⅜ in. to 2 in. thick. It works continuously day and night, and is operated by compressed air, having an effective pressure of about 80 lb. per sq. in. The sewage is treated with sulphuric acid, causing the solid matter to separate and deposit in settling tanks as sludge. This sludge contains some 80—85% water, and of the remainder some 30—40% is grease. Each filter press is worked for some 71 hours before a complete cake is formed, sludge being forced in for a couple of hours and then steamed well through for from ¾ to 1½ hours according to the amount of cake that has been formed. During the final ten hours the cake is not steamed, as nothing extra is gained. When finished it contains 15—18% of grease and 28—30% of water. Each press holds about 33 cwt. on the average, and this works out at about 78 lb. per cb. ft. The rate of filtration is about 0·06 gall. per sq. ft. per hour. The presses are fitted with pneumatic closing gear and have steam connections to the feed passage at each end of the press. Cotton twill cloths are used, as jute will not stand the steaming, and the life of the cloth is about 6—10 weeks.

About 40—50 presses are discharged per day, and it takes two men an average of about 10 mins. to open, empty and re-close a press, about three cloths being replaced. This gives a factor of 1·79. The total labour is four steamers for each shift, four emptiers, day shift only, and one man on trucks, day shift only. The total factor is, therefore, about 4. This excludes one night and one day supervisor.

It will be seen therefore that the labour required is very dependent on the class of operator and material, much more so than on the size and details of the press itself. This is emphasized by the fact that among the records in the author's possession is one relating to a press with 25½-in square recessed plates, having a number of ports formed in the rim, in which the discharging factor amounted to less than 0·9 when dealing with an intermediate product.

In conclusion it may be said that the best success of a filter press installation depends, not only on the choice of plant, but more especially on those in charge of the operations. It is nearly always possible to reduce high labour and cloth charges by proper methods in the lay-out of the plant, and especially in the formation of the precipitate or suspension, and those who take these facts duly to heart will get the most satisfactory results.

The author has to tender his best thanks to the many firms and individuals who have enabled him to collect various data and have given permission to use them for the present purpose. He has in most cases to respect the condition that these should remain anonymous, but he may especially mention Arthur C. Auden, Esq., M.Inst.C.E.; also H. Griffiths, Esq., A.R.C.S., B.Sc., who gave valuable assistance in criticising the proofs. He would also like to thank his wife, who prepared the various microscopic slides etc. for the camera, and carried out some useful researches in regard to filter cloths.

DISCUSSION.

Professor J. W. **HINCHLEY** said he only wanted to offer a word of appreciation on the paper. It was an excellent illustration of the work the Group could do, and he congratulated Mr. Alliott on the production of a model paper for the Group to listen to. He had taken the subject of the filter press in its two simpler forms, and he had given an exhaustive treatise on the subject, and one the Group would be proud of, and they were proud, he might say, of Mr. Alliott. There were, no doubt, many points in the paper to be elucidated as time went on. He was perfectly certain the formulæ he had put forward would be modified, but they were the basis for chemical engineering consideration of the subject of filtration. His admiration for the paper was as great as his admiration for Mr. Alliott's previous work, and he was hoping that the paper would stimulate many of them to attempt to do the same thing for other apparatus the chemical engineer used. There were points with regard to washing and with regard to formulæ they might go into, but he was inclined to think it would be better done by correspondence and by careful consideration of the paper rather than by discussion there. He thought they ought to ask everybody who had had anything to do with the filter press to send in some of his experiences so that the Group could publish a monograph on filtration which would be the standard work in this country. He would like to ask a question in regard to washing, as to whether when the washing took place in the reverse direction in the cake to which the filtration took place, Mr. Alliott had found any disturbing influence in the washing and any irregularity in the cakes.

The Chairman said that the stronghold of the filter press was in very good hands when it was defended by captains like Mr. Alliott. The name of Mr. Alliott and the company with which he was connected was a name which went all over the world.

Mr. **Alliott**, in reply, expressed his sincere thanks to M. Kestner and Professor Hinchley for their words of appreciation. He felt that he had been let down very lightly in view of the amount of material collected in his paper. He thought the question of exchange of data and works experience was a most important one, and that much benefit would accrue to everyone if this could be done more freely. In reply to Professor Hinchley he said he had not had any special difficulty in regard to reverse washing. It would depend somewhat on the type of cake.

The meeting then passed by acclamation a hearty vote of thanks to Mr. Alliott for his most interesting and important paper.

Second Session.

The second session was held in the Gaiety Theatre, Newcastle, on the morning of July 14. M. Paul Kestner, President de la Societe de Chimie Industrielle de France, occupied the chair, and there was again a large attendance.

At the commencement Mr. H. **Talbot**, Hon. Secretary of the Group, made a brief reference to the circumstances under which the Group met in that building, and said he would also like to refer to the presence of the distinguished gentleman who occupied the chair that day. Everyone who had even the slightest acquaintance with the chemical and allied industries would know M. Kestner's name, and would probably be acquainted with part, at any rate, of the very great work he had accomplished. Mr. Talbot said he need only recall to the minds of those present that M. Kestner was recently honoured by having bestowed upon him the gold medal of the Society of Chemical Industry. Throughout the time the Group had been in existence they had been fortunate in having the continued interest and the active personal support of M. Kestner.

M. **Paul Kestner**, in reply, said he felt intensely the very great value and the privilege which they had conferred upon him. He appreciated the kindness of all the members and the spirit in which he had been welcomed every time he had been amongst them.

MODERN LEAF TYPE FILTERS.

BY ROBERT C. CAMPBELL.

Note.—The word sludge will be used throughout this article to denote the material to be filtered.

While the principle of leaf type filtration has long been known, it has not been until recent years that filters employing this principle have been developed beyond the stage of a few special machines having each a very limited range of usefulness.

The efforts which have now brought leaf type filters into such high regard in the filtration field have been those resulting in the conception and development of suitable "filter machines" to utilize this principle to the greatest efficiency. The three machines which are best known and which have found the widest application in industry are the "Kelly" and "Sweetland" Pressure Filters and the "American" Continuous Vacuum Filter. The feature which recommends these filters is in each case the simple and substantial design which yet permits the necessary modifications to make them suitable for a wide range of problems.

Everyone is familiar with the common filter bag through which, from a solid-liquid mixture, the liquid passes under gravitational influence, while the solids, which are too large to pass through the pores of the cloth, are retained on the inside. This is the very simplest form of filter, and while in the Taylor Bag Filter it has been ingeniously developed for the clarification of syrups containing a low percentage of suspended solids, it is generally found unsatisfactory for commercial purposes where large volumes of material must be handled with expedition. The work of such a filter is, of course, limited by the effective pressure produced by gravity, but its greatest drawback lies in the cleaning operation, which is most laborious, involving the taking down of the bags full of mud, turning them inside out, washing them, and again setting to work.

If, however, such a filter bag is sewn over a wire screen frame which will hold the two sides sufficiently far apart to allow a drainage space between them, say a quarter of an inch, and a pipe nipple connection is made as the only outlet from the interior of the bag, this "filter leaf," as it is called, may be submerged in an open vessel of sludge and by the application of a vacuum to the nipple the clear liquid may be drawn through the cloth to the inside, then up the drainage space and out through the nipple while the solids in the sludge are retained in a uniform layer on the outer surface of the bag. This is the simplest form of leaf type vacuum filter.

Again, if this leaf were mounted in a closed tank so that the nipple extended out through a stuffing box in the wall as the only outlet therefrom and an inlet to the tank were provided through which sludge could be admitted under pressure, then as the sludge is pumped into the tank the clear liquor part will be forced through the filter cloth to the interior of the leaf and out through the nipple, while the solids will be retained on the outer surface of the bag. This is the simplest form of leaf type pressure filter.

Leaf type filtration accomplishes one most important object, namely, the suspended solids are retained on the outside of the leaf in a form which lends itself to a very simple and even an automatic method of cake discharge, as will be seen from the description of the filters.

The Kelly Filter was invented by Mr. David J. Kelly and was developed by the Kelly Filter Press Co. The Sweetland Filter was similarly invented by Mr. E. J. Sweetland and developed by him under the ægis of the Sweetland Filter Press Co. These two concerns combined several years ago under the name of the United Filters Corporation, and since that time this combination has developed the American Continuous Vacuum Filter.

Description of the Kelly and Sweetland Filters.

In brief, these machines consist of a series of filter leaves, substantially as described, mounted parallel to each other and at equal distances from centre to centre within a tank designed to stand the required pressure and which is of such a construction that the leaves can be completely exposed to view for cleaning in a short space of time by means of an automatic opening device.

In the Kelly filter this tank is cylindrical in form, set horizontally and provided with one removable head which is clamped in place by means of an automatic multiple radial lever locking device. The filter leaves are supported on a carriage attached to this head such that when the head is unlocked and withdrawn the leaves are brought completely out of the tank and in full view for

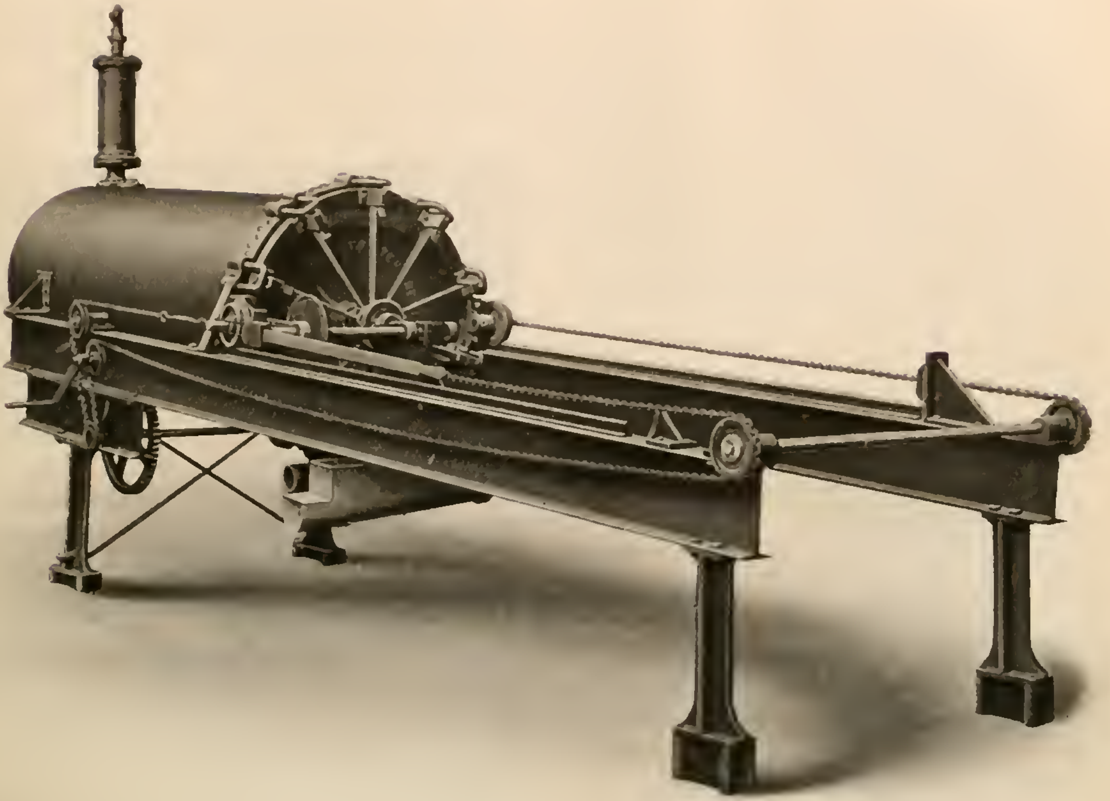


FIG. 1.
Hand-operated Kelly Filter, closed and locked, ready for filtering.

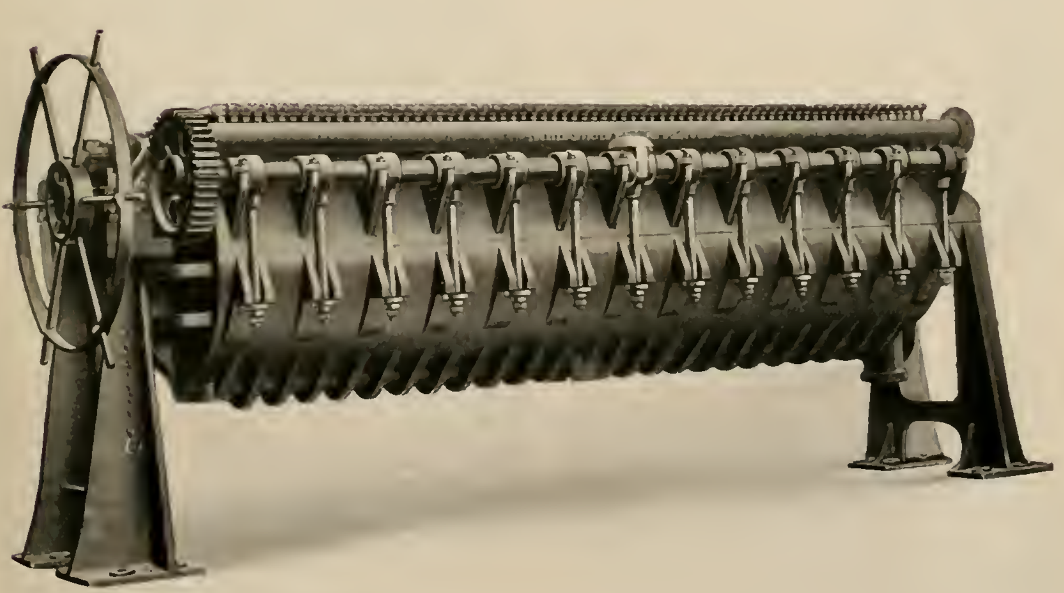


FIG. 2.
Sweetland Clam Shell Type Filter, closed, ready for operation.

cleaning. In the most modern type Kelly filter the whole opening operation is accomplished automatically by means of an air motor, controlled by one four-way valve.

The Sweetland Filter consists of a horizontal cast iron cylindrical tank split longitudinally into an upper and lower half. The upper half is supported on suitable legs at each end, while the lower half is hinged to and supported from the upper in clamshell fashion at the rear. The lower half is counterbalanced and is free to swing open and closed between the two legs at the ends of the filter. An eccentric shaft mounted on the front of the upper half carries a series of swing bolts designed to engage suitable lugs on the lower half so as to draw the two tightly together as the shaft is turned.

Inserted rubber gaskets are used in both the Kelly and Sweetland Filters to ensure a tight joint.

When it is desired to discharge the cakes from a Sweetland Filter the lower half is unlocked and swung down from beneath the leaves, exposing them to view and allowing the cake to be discharged direct into a suitable hopper or cart.

It will be seen that in the Kelly Filter the leaves are rectangular in form and as they are attached to the movable head they must have their outlets through it to a suitable receiving trough. The Sweetland leaves are circular in form and have individual outlets through the top of the filter with shut off cocks and sight glasses leading to a common closed manifold pipe.

The feed and drain connections for the Kelly are brought through the very bottom of the shell. The feed to the Sweetland is brought in at one end of the upper body, thus allowing a rigid pipe connection, thence through a cored passage to a distributing channel along the very bottom of the filter. Drain connections are provided from the lower body, but it is also possible to blow the excess sludge of wash water back through the feed lino in montejus fashion by admitting compressed air at the top of the filter.

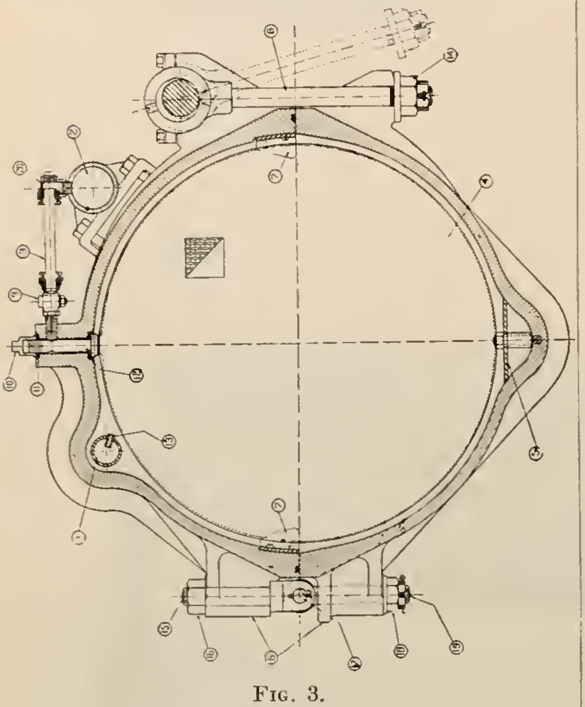


FIG. 3.

Cross section of Sweetland Filter showing :—

1. Internal Manifold. 2. Filtrate Manifold. 3 Sight Glass. 4. Filter Leaf. 5. Distributing Plate. 6. Adjustable Eyebolt type Rear Hinge. 7. Side Leaf Spacers. 8. Front Locking Bolts. 9. Filtrate Shut-off Cocks. 10. Cap Nut supporting Leaf. 11. Lead Washer. 12. Rubber Washer. 13. Sluicing Nozzle. 14. Locked Nut on Front Swing Bolt. 15. Fixed Top Eyebolt of Rear Hinge. 16. Nut supporting same. 17. Hinge Pin. 18. Take-up Nut on Lower Eyebolt. 19. Adjustable Lower Eyebolt. 20. Special Tee Connection from Gauge Glass to Manifold.

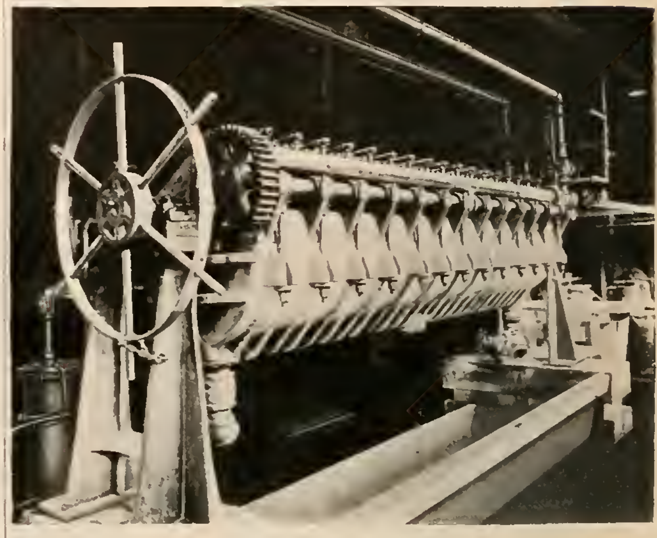


FIG. 4.

Sweetland Filter, closed and locked, ready for filtering.

Other connections generally used are an air vent from the top of the body to release the entrained air when filling the filter with sludge, steam or air connections to the filter body to facilitate draining or to dry the cakes, and steam and air connections to the filtrate manifold to inflate the filter bags and thus discharge the cakes. Both filters are built in a wide range of sizes.

Operation.

The operation of a complete cycle embodying filtration, washing the cakes free from soluble matter air drying and then discharging them, would be as follows :—

The air vent is first opened and then the feed turned on. As the sludge fills the body the air is forced out through the vent, then when sludge appears indicating that all of the air has been displaced the vent is closed. The pressure then builds up in the filter and filtration commences through the cloths. Filtration proceeds in a manner similar to a plate and frame press with the exception that the feed is stopped before the cakes on adjoining leaves build together. It is generally planned to leave a space of from one half inch to one inch between adjoining cakes. This is done to allow efficient washing as the wash water which passes through the cakes in the same manner as the filtrate must be able to reach every square inch of cake and also to allow room for the bags to inflate when discharging the cakes. The proper cake thickness is best reached by filtering a fixed quantity each cycle, or by filtering for the same length of time each cycle under practically identical pressures, or experience will enable one to judge from the rate of flow when it is best to stop, or in certain cases a cake thickness indicating device may be used which will give an alarm when the cake has reached the required size. The sludge feed valve is then shut off and if in the specific problem the volume of excess sludge between the cakes is small in comparison to the volume of the cakes, then the wash water may be followed through behind the sludge and a very efficient wash obtained. If the volume of excess sludge is relatively large, then there would be a considerable mixing of excess sludge and wash water in the body of the filter and a high percentage of water would be required to work this out and produce a satisfactory wash. In this latter case it is found advisable to drain the excess sludge using about five pounds of compressed air to hold the cakes in place while draining. The shell is then filled with water, thus completely submerging the cakes and the water is then forced through the cakes producing a most efficient wash.

When the gravity of the effluent wash water has fallen to zero indicating that the solubles have been completely displaced from the cakes, the water supply is shut off and the excess water in the filter drained using a low air pressure until the water is all out, then the drain valve is closed and the air pressure increased sufficiently to pass through the cakes to blow out as much moisture as possible. As the moisture is driven out of the cakes there is a consequent reduction in their volume which manifests itself in a shrinkage along the exposed surface causing cracks to appear. The number of these cracks soon increases to such an extent that most of the air is found to be passing through them rather than through the cake proper. It is inadvisable to attempt further drying beyond this stage.

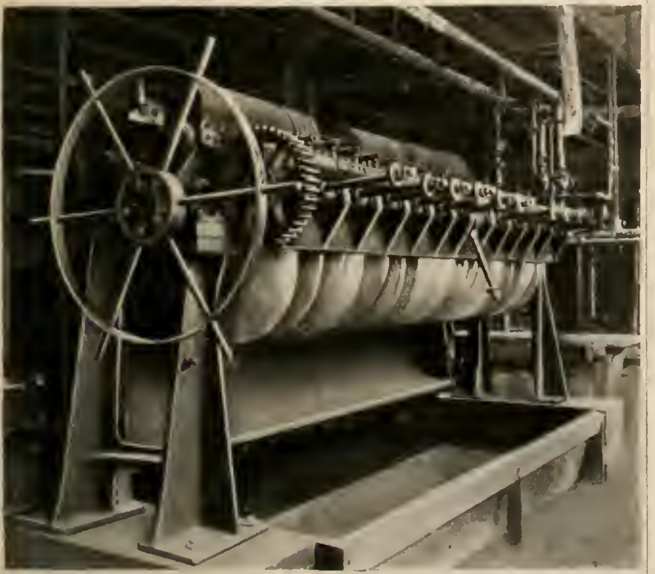


Fig. 5.

Sweetland Filter, opened as when discharging cakes.

The air may now be shut off and the filter opened. The discharge from the filtrate manifold is then closed and air or steam admitted to it so as to pass back into the bags and inflate them, thus loosening the cakes. Cakes of three-quarters of an inch thickness or more will generally fall of their own weight, cakes thinner than this often need to be assisted with a paddle or an air or water hose. Very thin cakes as are encountered when clarifying sugar refinery liquors are washed off automatically in the Sweetland Filter by means of a special sluicing device.

Filtering and Washing.

Efficient washing implies the required partial or complete displacement of the mother liquor filling the spaces between the cake particles with the least possible amount of water or other washing solution.

The manner in which the filtration has been conducted has a great bearing on the washing results, for unless the cakes have been so deposited that every square inch is of uniform consistency, even thickness, and equal resistance, the washing will not proceed evenly and it will be necessary to overwash some parts in order sufficiently to wash others. This applies to any type of filter or centrifugal machine.

If the suspended solids are of uniform consistency and low specific weight no special effort is required to produce such a cake, but if the solids be of high specific weight implying fast settling or if a mixture of the two is being worked, then it is advisable that a good circulation be maintained in the filter body throughout the whole filtration period. This will prevent the heavier particles separating from the lighter ones and settling to the bottom of the filter. If the natural rate of filtration is not sufficient to produce this circulation, then a connection may always be made from the body of a leaf type filter back to the supply tank and sufficient sludge may be circulated in this manner to produce the desired results.

The wash water will than pass uniformly through the cakes and force the mother liquor ahead of it in a body. Continuous sampling will show that the effluent wash water is of the same specific gravity as the filtrate for quite a period and then drops rapidly to zero. If the gravity of the effluent wash water begins to fall at the start of the wash and continues to drop slowly it is a sign that the cakes were not properly formed or that they have been cracked or disturbed between the filtration and washing period.

Washing generally requires a weight of water equal to from 85—125% of the weight of the discharged cake; 100% being considered very satisfactory.

Cleaning.

Scraping the cakes off a filter cloth against a plate or leaf is to be avoided, for it not only wears the cloth but smears some cake into it as well.

Leaf type filters possess the advantage that the bags can be inflated to loosen and discharge the cakes. This opens the pores of the cloth and keeps it free filtering. Only in rare cases is it necessary to scrape the cakes from the bags, and if they are kept inflated while scraping the air passing through the cloth prevents any cake being smeared into it. Certain salts are met with which become precipitated in the fibres of the cloth due to the decrease in pressure from the filter body through the cloth to the atmosphere. These can generally be removed by filling the body with a dilute acid solution and allowing the filter to stand for an hour or so. It is not necessary to remove the frames from the filter for acid or soda washing.

Drying.

Cakes formed of rigid non-compressible particles have drying limits which are governed by the physical qualities of the material rather than the type of filter used, but when the particles are soft and compressible it is to be expected that a plate and frame press will produce a more compact and drier cake than a leaf type filter.

Description of the American Continuous Vacuum Filter.

The American Continuous Vacuum Filter is built up first of a shaft to which several spiders are permanently attached. These spiders support and rigidly hold in place a series of manifold pipes equally spaced in a circle close around the shaft. The manifold pipes are capped at one end and terminate in individual ports in the casing of a rotary valve at the other end. They have also ports drilled along their length to correspond with the position of and to form the outlets from the filter leaves.

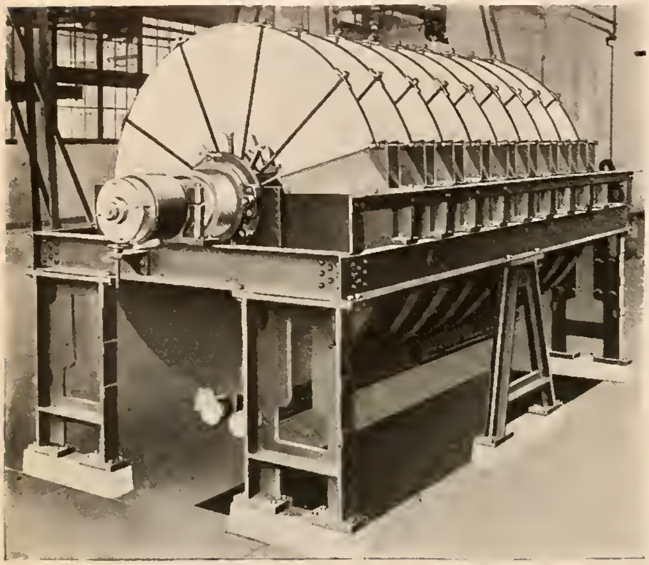


Fig. 6.

Nine-disc standard iron construction American Continuous Vacuum Filter.

The filter leaves which are of sector shape are of a construction capable of standing compression, and when inserted in place about the shaft form a complete disc. They are held in place by a series of steel tension spokes radiating from the centre shaft and provided with clips and tightening nuts on the end. Drawing up these nuts brings the outlet nipples at the inner end of the leaves down tight against the gaskets in the ports of the manifold pipes. This construction makes a very rigid disc, and at the same time a very direct leak-proof connection from the leaves to the rotary valve. The filters are built in several standard diameters and in various lengths to allow from one to eight such discs to be mounted on the shaft as a unit. The whole is supported in bearings over a suitable semi-circular pan containing the sludge, which pan is cut back on one side between the discs so as to allow the dry cakes scraped therefrom to fall direct to a receptacle beneath the filter.

The plug of the rotary valve previously mentioned has four parts, and as it is held stationary while the machine revolves each port in the casing functions with those in the plug in turn. The first is a high vacuum port connecting with all the filter leaf sectors which are completely submerged in the sludge, thus drawing the solution through the filter leaves and causing the cakes to be formed. A second vacuum port connects with those sectors which have just emerged from the sludge and on which the cakes require washing and drying. The third is a compressed air port to inflate the bags as they approach the scrapers, and the last is an exhaust port to release the entrained compressed air as the sectors again submerge, thus reducing the work of the vacuum pump.

Other features which deserve mention are (A) The system of washing the solubles from the cakes which consists of a series of atomisers which maintain a thin layer of water on the exposed cake surface. The vacuum draws this water through the cake, thus displacing the solubles.

(B) The cake scrapers, which are of metal construction, rubber-edged, are set to clear the discs by about three-eighths of an inch, then as each sector approaches these scrapers the bag is inflated to bring it out to the scraper edge, thus overcoming the danger of pinching or cutting the cloths which would occur if the scrapers actually bore against the sectors.

The inflation of the bags further opens the pores and keeps them free filtering, ensuring a continued high capacity during their full life.

The valve plug has a tapered seat ground to fit the casing and is held tight in place by an adjustable spring. It requires very little attention as the spring takes up what little wear may occur.

The advantages which recommend this type of filter over other continuous vacuum filters are:—

Greater filter area per sq. ft. of floor space.

Lighter weight per unit of filter area.

Simple and accessible construction.

Continued high capacity due to the cloths being kept flexible and free filtering.

The sectors can be quickly changed and a spare one inserted in place of one having a worn-out cloth in a very short time.

Owing to the perfect drainage from the bottom of the sector during the drying position no moisture is blown back during the cake discharge, hence the driest possible cake is assured.

Low maintenance costs. Every part that is subject to wear can be easily replaced.

Operation.

The general scheme for the connections from the valve of the filter to the accessory equipment is shown in the accompanying cut. The foam trap shown is not always necessary, and if a thirty foot fall can be obtained from the vacuum receiver, a barometric leg may preferably be used in place of the centrifugal pump. When it is desired to keep the wash water separate from the filtrate a second vacuum receiver may be installed in the same manner as the one shown. Some means of maintaining a constant sludge level in the filter should be employed. This can be done by means of a float valve, or when fast settling solids are encountered it is generally best to feed in at the bottom of the filter a large enough supply to overflow a good stream from the top back to the supply tank, thus keeping up a good circulation.

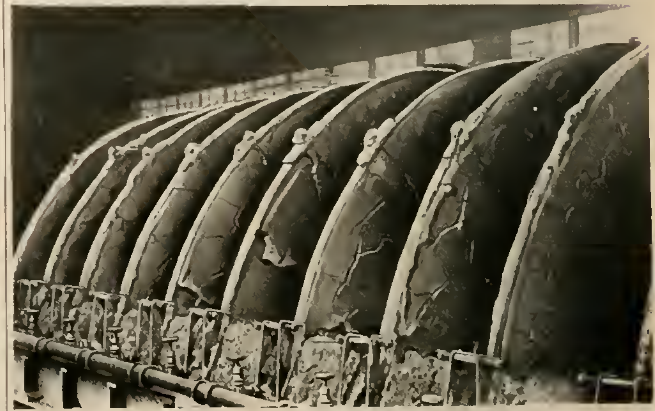


Fig. 7.

American Continuous Vacuum Filter in operation, showing cakes being removed as inflated bags pass through the scrapers.

The pan is first filled with sludge, then the filter is started turning, after which the vacuum and centrifugal pumps are started. It is sometimes best when starting to keep the drying and inflation ports closed until one revolution has been completed and a cake built on all the sectors, for if the drying port were open when there was no cake on the exposed surface it would be difficult to pull a good filtering vacuum.

Vacuum filters generally operate at a speed of from two to twelve minutes per revolution, depending upon the filtering quality of the material, six minutes being a good average speed.

Field of usefulness of each filter.

In general, the Kelly may be said to be suitable for the filtration of sludges containing from less than 1% of suspended solids to those containing the highest percentage of solids which can be conveniently pumped to and drained from the filter, wherein it may or may not be required to wash the cakes free from solubles with water, a solvent solution or a chemical reagent, and then to force as much excess moisture from them as possible by the use of compressed air or steam, and wherein in every case it is practical to build a cake of greater than one quarter inch thickness.

When equipped with Sweetland's Patent Monel Metal Filter Cloth, this filter is widely used for the filtration of caustic liquors directly after the causticising reaction has been completed, and also for the removal of Fuller's Earth from vegetable oils after bleaching. The metal cloth is, of course, nonabsorbent, and, further, without injury to itself allows the cakes to be thoroughly steamed to reduce the oil content to the lowest possible figure. In general, it may be said that a metal cloth equipped Sweetland will show a 20% lower oil loss than other filters employed for this work.

The American Continuous Vacuum Filter is to be recommended for sludges containing over 15% of comparatively free filtering solids, wherein a cake of greater than one quarter inch thickness may be built with vacuum in from one to eight minutes. Thinner cakes can be handled, but in most cases a thin cake indicates that the sludge builds too impervious a cake to allow efficient filtration under vacuum or that the percentage of solids in the sludge is too low. In the first case it would probably be more advantageous to use a Kelly or a Sweetland Filter, while in the second a continuous thickener could be used to advantage before the filter to bring the feed up to the required consistency. The Dorr or the Genter continuous thickeners are to be recommended for this purpose.

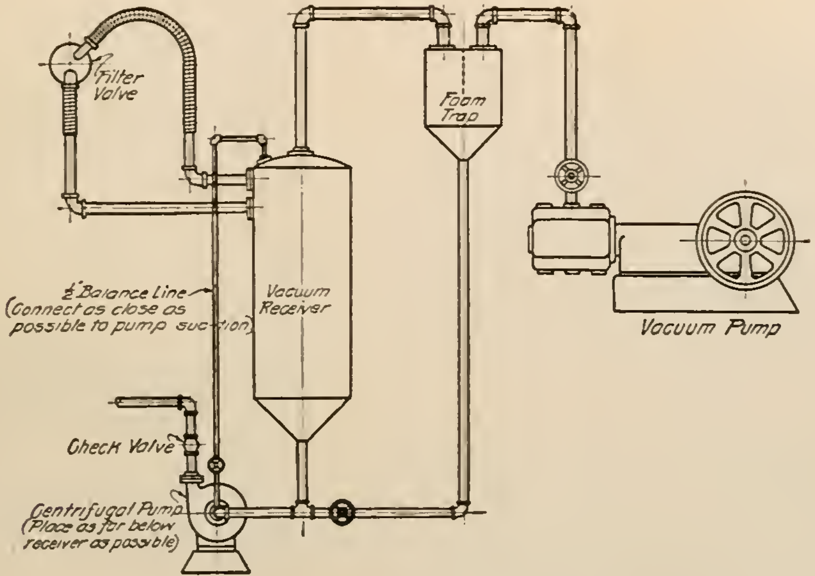


FIG. 8.

Piping connections for an American Continuous Vacuum Filter.

The Sweetland Filter will satisfactorily handle the same problems as the Kelly, and in addition is to be especially recommended for the clarification of free filtering or viscous solutions containing such a small percentage of finely suspended colloidal or gummy solids that it becomes necessary to add a small amount of Kieselguhr or some other filter aid to the solution to assist the filter cloth in retaining these solids or to accelerate the rate of flow. In such cases the cakes, which seldom exceed one-eighth of an inch in thickness, may be conveniently washed from the cloths by means of the internal sluicing manifold without opening the body proper from one cycle to another. This unique feature of the Sweetland Filter finds wide application in the sugar refineries, where over two hundred and fifty large size machines have been installed in the last six years.

As each leaf in the Sweetland Filter discharges into a common closed manifold pipe, this filter finds a wide application in those industries where the cakes must be washed with a volatile solvent.

The cakes may be washed by continuing the vacuum as the sectors emerge from the sludge and applying water to the exposed cake surface in the form of a very fine mist by means of spray nozzles. The cakes may then be air dried by continuing the vacuum after the sectors have passed through the washing zone until it becomes necessary to cut off the vacuum and admit compressed air for the discharge.

As the time of washing is restricted to a certain part of the revolution some cakes containing a high percentage of solubles cannot be completely washed in one cycle and must be puddled with water and refiltered. For such materials it may be best to use a pressure filter.

A brief list of the principal industries in which these filters find satisfactory use is given on next page.

Kelly and Sweetland Filters.

Beverages.
Chemicals.
Coal tar products, creosote, etc.
Dyes.
Edible oils:—Vegetable, fish.
Fruit juices.
Mineral oils.
Lubricating and cutting oils.
Mining:—Cyanide and flotation processes.
Pigments.
Starch.
Sugars:—Sugar cane juices, refinery liquors, beet sugar juices.
Varnish.

American Continuous Vacuum Filter.

Beet sugar products.
Dewatering cement slurries.
Chemical plants.
Clay washing plants.
Dyes.
Mining:—Cyanide and flotation processes.
Pigments.
Starch.

Capacity of filters.

In order to select the correct size pressure filter for a given proposition it is first necessary to determine from experience or by laboratory experiments the time required for a complete cycle and (A) the number of cycles that can be made in a working day. This, of course, depends on the physical nature or filtering quality of the material and whether the cakes must be washed, dried, etc. The laboratory experiment should also show (B) what is the most economical cake thickness to build expressed in inches, (C) the percentage of moisture left in the cakes as discharged, and (D) the weight of the cake in pounds per cubic foot as discharged.

Let (W) equal the weight of dry solids to be filtered per day, then

$$(\mathrm{W}) \div (\mathrm{A}) \times \frac{100}{100-(\mathrm{C})} \times \frac{1}{(\mathrm{D})} \times \frac{12}{(\mathrm{B})} =$$

the required filter area.

A filter should be chosen having this area with the leaves spaced at from [2 (B)+1]″ to [2 (B)+2]″ centre to centre.

Normal rates of filtration vary from one-half to twenty gallons per square foot per hour.

In view of the fact that continuous vacuum filters cannot cover the wide field for which pressure filters are adapted, and are only to be recommended for those problems which are known to be to their liking, it is quite safe to say that their capacity will lie between the limits of from 300 to 700 lb. of dry solids per square foot of filter area per twenty-four-hour day. Capacities as low as 100 and as high at 2000 lb. have been noted, but these are unusual.

Labour requirements.

Kelly and Sweetland Filters.—When the filter station has been properly laid out for convenient operation one man can take care of from three or six filters. It is found to take from six minutes to open the filter, dump the cake and close it again ready for the next cycle when handling a heavy relatively dry cake which will fall of its own weight when the bags are inflated, to twenty minutes for those thin viscous cakes which must be scraped off by hand or otherwise removed as, for example, by means of a compressed air or water hose.

In the case of Sweetland Sugar Refinery Filters wherein the thin cakes are sluiced off, the cloths can be washed clean in from six to twelve minutes. Automatic devices have been developed to operate the sluicing pipes, and when these are used one man can tend to as many as eight to ten filters.

American Continuous Vacuum Filters.—When these filters are properly installed there is very little for the operator to do after starting them up save oil the bearings, keep an occasional eye on the vacuum and pressure gauges, and then watch the machines revolve. One man may tend to from one to ten filters.

Accessory equipment and power consumption.

Kelly or Sweetland Filters.—The items of accessory equipment in the case of Kelly or Sweetland Filters which consume power are as follows:—

(A) Main feed pump or montejus supplying the filter.
A pump should be chosen, preferably a single stage centrifugal, capable of delivering the average volume of sludge to be filtered per minute at a pressure of 50 lb. per square inch.

(B) Wash water pump if the local supply pressure is not satisfactory.
A pump of about half the capacity of the sludge pump should be chosen. It should be able to deliver this capacity at 50 lb. pressure.

(C) Air compressor to furnish air for drying the cakes and also to facilitate draining the excess sludge and wash water.
The air compressor should have a capacity of from 12 to 30 cubic feet of free air per square foot of filter area during the filtering period and should be able to compress this to 50 lb. pressure.

(D) Steam if found advisable in place of compressed air.

(E) Compressed air or water where power devices are used for closing the filter. (Requirements very small.)

(F) When Sweetland Filter cakes are to be discharged by means of the sluicing device a supply of 3·5 galls. of hot water per leaf per minute will be required at 75 lb. pressure for a period of from six to twelve minutes.

American Continuous Vacuum Filter.

(A) Main dry vacuum pump.
This should have a displacement of ·6 to 1·25 cu. ft. of free air per square foot of filter area per minute.

(B) Compressed air to inflate the bags as they approach the scrapers.
The air compressor should have a capacity of approximately ·08 cu. ft. of free air per minute per square foot of filter area compressed to 2 lb. pressure.

(C) Power to drive filter.
The power required to start the filter will be about ·005 h.p. per square foot of filter area, but once it is in motion the power consumption will drop to one-half this figure.

(D) Centrifugal pump.
In cases where there is not a sufficient drop below the filter to employ a barometric leg to remove the filtrate from the vacuum receiver, and a centrifugal pump must be employed for this purpose, there will be an additional power consumption, but it can be stated that the total power consumption for all of the above items should not exceed ·06 h.p. per square foot of filter area when starting up, and approximately one-half of this when in continuous operation.

Filter cloth consumption.

Sweetland and Kelly filters are in almost every case installed to replace plate and frame type filters, apart from new installations. The saving in the filter cloth costs is one of the important items affecting the decision in favour of the leaf type filters. The filter cloth in a plate and frame filter serves not only as the filtering medium but also as the gasket between adjoining plates and frames. A much heavier cloth than is required for the actual filtration is therefore used, and in most cases it is found that it first gives away along the inner edges of the frames due to the mechanical strain. The cloths in a leaf type filter are freed from this gasket duty, and therefore show a much longer life. A lighter cloth can also be used. Savings of over 50% in the cloth bills are quite common. However, in cases where the solution being filtered has a deteriorating action on the cloth, it cannot be said that either type filter can reduce this in any way.

The American Continuous Vacuum Filter is on the whole even more economical of filter cloth than the Kelly or Sweetland.

Special Construction.

The standard Kelly-Sweetland and American filters are of iron and steel construction, but where solutions are met with which attack these metals special materials may be employed.

It is difficult in an article of this length to do justice to a subject having so many phases and so the writer has merely attempted to give just a sufficient description of each machine to enable him to bring out the points of information as to method of operation, field of usefulness, efficiency, etc., which he believes will be most important to those who must contend with problems of filtration.

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